CONSULTANT REPORT

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Public Interest Energy Research
CALIFORNIA ENERGY COMMISSION

Energy-Related
Environment Research

BIRD STRIKE MONITOR

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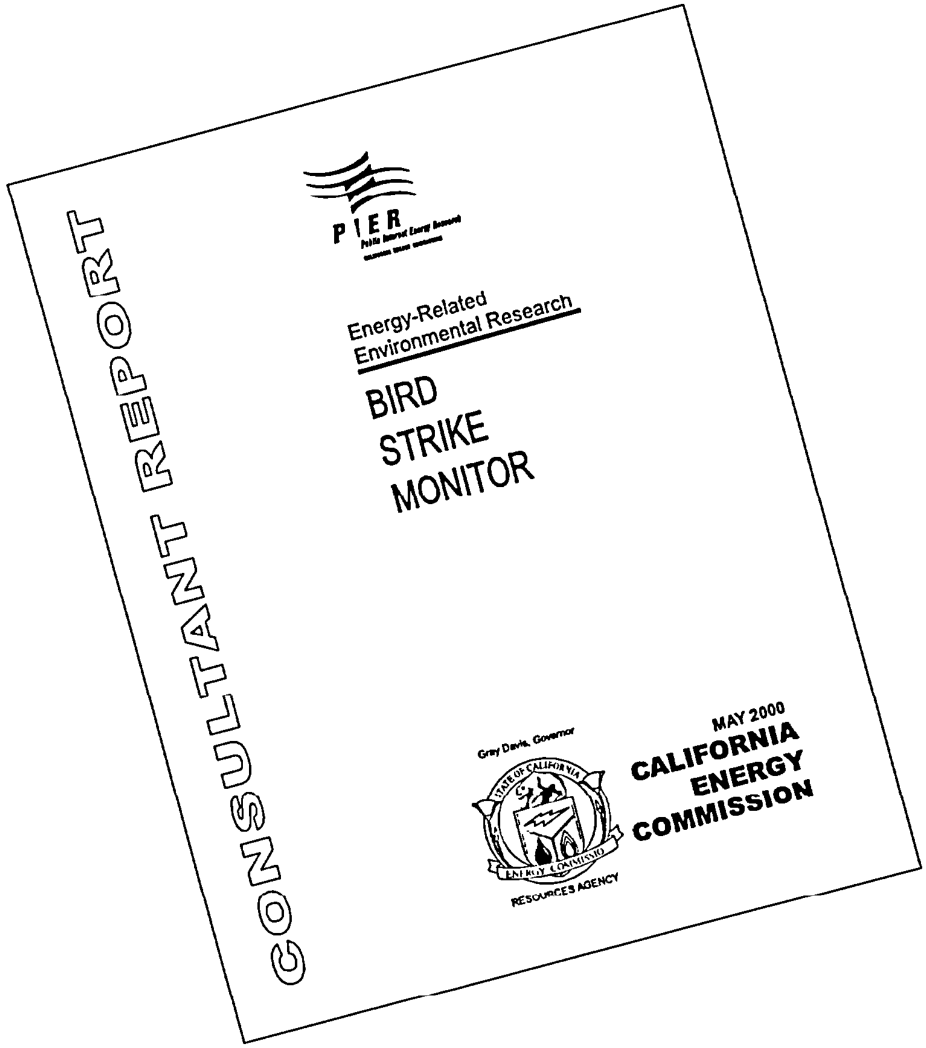

CALIFORNIA ENERGY COMMISSION

Prepared for:
CALIFORNIA ENERGY COMMISSION

Prepared by:
Sheila Byrne
Technical and Ecological Services
PACIFIC GAS AND ELECTRIC COMPANY

San Ramona, CA

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Linda Spiegel, *Project Manager*

ENVIRONMENTAL OFFICE

Robert Therkelsen, *Deputy Director*

ENERGY FACILITIES SITING & ENVIRONMENTAL PROTECTION DIVISION

Gary Klein, *Contract Manager*

ENERGY TECHNOLOGY DEVELOPMENT DIVISION

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Acknowledgements

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Preface

The Public Interest Energy Research (PIER) Program supports public interest energy research and development that will help improve the quality of life in California by bringing environmentally safe, affordable, and reliable energy services and products to the marketplace.

The PIER Program, managed by the California Energy Commission (Commission), annually awards up to $62 million through the Year 2001 to conduct the most promising public interest energy research by partnering with Research, Development, and Demonstration (RD&D) organizations, including individuals, businesses, utilities, and public or private research institutions.

PIER funding efforts are focused on the following six RD&D program areas:

- Buildings End-Use Energy Efficiency
- Industrial / Agricultural / Water End-Use Energy Efficiency
- Renewable Energy
- Environmentally-Preferred Advanced Generation
- Energy-Related Environmental Research
- Strategic Energy Research.

In 1998, the Commission awarded approximately $17 million to 39 separate transition RD&D projects covering the five PIER subject areas. These projects were selected to preserve the benefits of the most promising ongoing public interest RD&D efforts conducted by investor-owned utilities prior to the onset of electricity restructuring.

What follows is the final report for the Bird Strike Monitor project, one of nine projects conducted by Pacific Gas and Electric Company. This project contributes to the Energy-Related Environmental Research program.

For more information on the PIER Program, please visit the Commission's Web site at: http://www.energy.ca.gov/research/index.html or contact the Commission's Publications Unit at 916-654-5200.

Executive Summary

Birds can be injured or killed from collisions with overhead conductors or ground wires (Brown et al. 1984, APLIC 1994). For species with limited numbers, this mortality can be significant to the population as well as the individual (Brown et al. 1987, Crivelli et al. 1988). Bird strikes with powerlines can also result in temporary power outages.

Several factors lead utilities, resource agencies, and others attempt to quantify bird collisions with wires. First, appropriate remedial action can significantly reduce collisions (Morkill and Anderson 1991, Brown and Drewien 1995). Common methods used to reduce collision mortality include various types of line marking devices. But as these are expensive to install, and may cause visual impacts, their use should be justified. Second, resource agencies and environmental groups are increasingly concerned about bird losses from collisions. Studies of collision rates may be needed for permitting documents, or to address concerns raised by agencies or the public. The method used for these studies must be sufficiently reliable that all parties will accept the results.

Developed in the late 1970s to provide worst case estimates of potential bird mortality for use in environmental assessment documents, the current methods to identify hazardous lines and count bird collisions are both labor intensive and unreliable. The most commonly used method is to search under wires for dead birds, they may be difficult to detect, removed by scavengers, or decomposed. Dead bird searches may be impossible in locations over water or wetlands, yet powerlines in these habitats are known to be particularly hazardous to birds (Faanes, 1987). And unless reinforced by direct observations of strikes, correlations with specific line outages, or the presence of characteristic injuries, finding dead birds under lines provides only circumstantial evidence of collisions. Nevertheless, estimates of collision mortality are commonly based on dead bird searches. In addition, inaccuracies are multiplied by corrections for biases presumed to be present in the methods (APLIC 1994).

In an effort to find a more cost-effective and reliable technique of detecting bird collisions with wires, the Pacific Gas and Electric Company developed a prototype Bird Strike Monitor in 1995. The monitor was designed for use by transmission and distribution line owners and regulatory agencies to identify and mitigate powerlines responsible for collision-caused bird mortalities.

Objectives:

The overall goal of this project was to advance the development and testing of the Bird Strike Monitor to the point where it could be released for fabrication or construction and confidently used in studies of bird strikes. The objectives were to:

- Redesign and improve the Bird Strike Monitor
- It must be affordable, small, lightweight, and easy to install.
- Conduct performance tests that simulated live bird strikes with wires to determine the correlation between actual strikes and those recorded by the Bird Strike Monitor.

Outcomes:

This project produced two major outcomes:

- Design of the Bird Strike Monitor ground station was documented.
- The bird strike monitor as designed and tested did not produce consistently reliable data. We were unable to correlate the number of bird strikes recorded by the monitor with dead birds or their remains. The primary reason for performance test problems was the drastically changed radio interference environment.

Conclusions

The project demonstrated that the design of the bird strike monitor is no longer functional in areas with significant radio traffic in the 900 MHz range. Nevertheless, the system must be able to perform in hostile environments to be credible.

- To produce a bird strike monitor that will reliably record bird strikes, the current system will have to redesigned and incorporate a new radio and new software.
- Existing design can only be used in areas where radio site surveys have shown that radio interference would cause data corruption.

Recommendations

To encourage further development of the system, the following recommendations are offered:

- Obtain recommendations from specialists in wireless data communication special applications on radio frequency bandwidth and technology for future radio selection.
- Depending on the radio chosen, develop software to take advantage of the technology's abilities to resist interference.
- Since the radio must be changed, the monitor's circuit board must be redesigned, and hardware modified. New waterproof housing is required, and can be designed to accommodate the new components.
- Upgrade the data collection method to make it Internet and pager-capable. This system would call the ground station as frequently as desired, and the software would conduct an automatic download of the ground station. If data were available for download, the software would email or page people on a real time alert.
- Additional improvements can be made to the functionality of the system:
  - Upgrade ground station hardware and software by adding an up-to-date single board computer and flash-memory storage system. The ground station could automatically call the server to announce that a bird strike had occurred and transmit its data seconds after the sensor had activated. This feature could be quite helpful if it led to the discovery of a downed bird before the carcass was lost to predators.
  - It would be useful to have a method of changing the monitor's trigger point short of burning in a ROM chip.
  - Clean up minor bugs in ground station software and the modem interface program.
- Once the necessary changes have been made to the system's design, it is critical that prototypes be thoroughly tested in the laboratory and the field.

Benefits to California

The Bird Strike Monitor would benefit California electric ratepayers by providing an improved method of detecting bird collisions with overhead wires, allowing utilities to more easily identify spans in which mitigative measures are needed. It would also be very useful in evaluating the effectiveness of marking and other measures used to reduce bird collisions with wires. Since bird collisions can cause outages (mainly momentary outages), reducing bird strikes contributes to improved electric reliability as well as enhanced environmental quality.

Although the Bird Strike Monitor Performance Testing Project fell short of its original goals, it identified a conflict between the technology and the recent proliferation of wireless communications devices. This conflict must be resolved to ensure reliable data collection. The funds provided by the California Energy Commission have allowed us to document the system sufficiently to allow development to continue.

Abstract

The goal of this project was to complete development and testing of the Bird Strike Monitor, a device that detects and records bird strikes with powerlines. The objective was to develop a monitor that would provide a more accurate and less costly method of measuring the number of bird collisions with powerlines.

Pacific Gas and Electric Company's Research and Development Department developed the Bird Strike Monitor, which was field tested near Klamath Falls in 1995 and 1996. The field testing showed that the Bird Strike Monitor could reliably record bird strikes, but it did not yield an unequivocal correlation between dead birds and monitor strikes, mostly due to a paucity of bird strikes. It was felt that additional testing would show that the monitor reliably recorded all bird strikes.

We proposed to test the monitor in a controlled situation. A bird cannon was built to propel dead birds (or other objects) at a test line. We also proposed to make several improvements to the system to correct deficiencies discovered during the Klamath Falls testing.

However, the performance testing did not produce reliable data. A large percentage of strike records suffered from corrupted data from loss of bites in transmission. The waveforms obtained from the corrupted data were similar to each other, but different from almost anything obtained during laboratory and field tests in 1995. After much troubleshooting, we traced the problem to radio interference in the 900 MHz band used by the monitor's transceivers. This was compounded by the lack of retransmission protocols.

The solution is to use another radio. Changing the radio is not trivial – it requires that several components of the monitor be redesigned, and both hardware and software modified. The redesign was beyond the scope of this project. We have documented the hardware and software of the current system to further the Bird Strike Monitor's development. Although the project failed in its original objective, it clearly indicated the modifications needed to make the monitor work in today's wireless environment.

1.0 Introduction

Migratory and resident birds can be injured or killed from collisions with overhead conductors or ground wires (Brown et al. 1984, APLIC 1994). For species with limited numbers, this mortality can be significant to the population as well as the individual (Brown et al. 1987, Crivelli et al. 1988). Bird strikes with powerlines can also result in temporary power outages.

Two major factors lead utilities, resource agencies, and others to attempt to quantify bird collisions with wires. First, appropriate remedial action can significantly reduce collisions (Morkill and Anderson 1991, Brown and Drewien 1995). Common methods used to reduce collision mortality include various types of line marking devices. But, these can be expensive to install and may cause visual impacts. Second, resource agencies and environmental groups are increasingly concerned about bird losses from collisions. Studies of collision rates may be needed for permitting documents, or to check concerns raised by agencies or the public. The methods used for these studies must be sufficiently reliable that all parties will accept the results.

Developed in the late 1970s to provide worst case estimates of potential bird mortality for use in environmental assessment documents, the current methods to identify responsible lines and count bird collisions are labor intensive and unreliable. The most commonly used method is to search under wires for dead birds. They may be difficult to detect, removed by scavengers, or decomposed. Dead bird searches may be impossible in locations over water or wetlands, yet powerlines in these habitats are known to be particularly hazardous to birds (Faanes, 1987). And unless reinforced by direct observations of strikes, correlations with specific line outages, or the presence of characteristic injuries, finding dead birds under lines provides only circumstantial evidence of collisions. Nevertheless, estimates of collision mortality are commonly based on dead bird searches. In addition, inaccuracies are multiplied by corrections for biases presumed to be present in the methods (APLIC 1994).

To provide an alternate, potentially more accurate method, Pacific Gas and Electric Company developed the Bird Strike Monitor as a cost effective, reliable technique of detecting bird collisions with wires. The monitor is designed for use by transmission and distribution line owners and regulatory agencies to identify and mitigate powerlines responsible for collision-caused bird mortalities. It must be affordable, small, lightweight, and easy to install. It should function on energized or unenergized conductors of commonly used voltages. To be acceptable to regulatory agencies, the system must be shown to obtain reliable, rigorous data that can be correlated with data collected by conventional dead bird searches.

1.1. Previous Development Efforts

The limitations of dead bird searches to estimate bird mortality were recognized early, and inspired efforts to develop better technologies for detecting bird collisions with wires. To improve data collected during dead bird searches, Willdan Associates (1981) developed an experimental impact detection system that consisted of an accelerometer clamped to the overhead ground wire of a Bonneville Power Administration 500 kV transmission line. Data was transmitted through fiber optics cables to a tape recorder. This approach proved too sensitive to distinguish between bird collisions and other wire vibrations, and the direct connection between the accelerometer and recorder presented line outage problems.

The Pacific Gas and Electric Company (1993) attempted to resolve these problems by adapting a line vibration sensor originally developed by Nitech, Inc. (known as the Nitech Power Donut). In this sensing device, power was derived from a line's own magnetic field. Digitized vibration data from an accelerometer were transmitted to a ground station via radio transmission. The device could be mounted on a conductor without taking the line out of service. The prototype Pacific Gas and Electric Company bird / powerline collision detection system appeared capable of eliminating most problems inherent in dead bird searches, such as the uncertainties in bias estimation and time-consuming overflight data collection. However the system was too expensive at $25,000 per sensor unit to be used in most bird powerline studies. It was bulky and heavy, and could not be used on to be on unenergized lines or on lines less than 115 kV. Finally, it was never proven in actual field research.

1.2. Project History

In 1994, The Pacific Gas and Electric Company initiated research on a new Bird Strike Monitor design (Byrne, 1997). The new unit was smaller, cheaper, and more reliable than the donut, and did not have to be powered from an energized line. Twelve prototype units were constructed and subjected to mechanical and electrical tests in Pacific Gas and Electric Company's Technical and Ecological Services (TES) Department High Voltage Test Facility. The Bird Strike Monitor performed well during both energized and unenergized laboratory tests. Impact forces were reported reliably.

The Pacific Gas and Electric Company then field-tested the Bird Strike Monitor near Klamath Falls, Oregon, in a cooperative effort with PacifiCorp. The field tests ran for ten weeks in the fall of 1995, with dead bird searches conducted during eight of those weeks. They resumed for eight weeks in the spring of 1996, with dead bird searches for six weeks. The dead bird searches were to demonstrate a relationship between monitor signals and dead birds or their remains found on the ground. During fall 1995, one monitor strike could be correlated with a feather spot. In the spring of 1996, a dead bird or feather spot could be associated with a recorded monitor strike in six instances. However, of these seven hits only one was overwhelmingly convincing – a strike was noted at 3 a.m., and a dead American coot was found under that conductor the next day.

Field tests showed two types of non-correspondence: dead birds that could not be matched to a monitor strike, and monitor strikes not associated with dead birds.

The first type of non-correspondence is more serious, since it would indicate that birds were striking conductors and not being recorded by the monitor. Close examination of the data did not indicate any instances of this type of error. The second type is less serious as it may indicate that a bird struck the line lightly and flew on, or that the line was struck by something other than a bird. In the fall of 1995, three monitor hits, all in November, did not match dead birds. In the spring, 16 recorded monitor hits were not associated with any bird remains.

It was felt that the field trial, although promising, did not produce enough data to adequately test the bird strike monitor. Furthermore, the field test did not allow for direct observation of strikes on the lines. Thus, data interpretation was somewhat subjective. And while biologists must often tolerate ambiguity, the initial proving of a methodology should produce a high degree of confidence. Release of the monitor following the Klamath Falls tests would have been premature. Additional testing in a more controlled situation was indicated. Actual strikes should be observed, either visually or by camera. Until each record can be confidently explained, the data are subject to misinterpretation, exaggeration, or incredulity.

Before additional tests could be initiated, electrical industry restructuring eliminated the Pacific Gas and Electric Company's budget for research and development (R&D) and, in 1997, the company eliminated its R&D Department. The R&D Electrical Laboratory and its technicians, who had developed the monitor, left the company or moved to line organization jobs. However, the California Energy Commission provided funding to continue selected projects from Pacific Gas and Electric Company's R&D group. This project benefited from their support.

1.3. Objectives

The overall goal of this project was to advance the development and testing of the Bird Strike Monitor to the point where it can be released for fabrication or construction and confidently used in studies of bird strikes. The objectives were to:

- Redesign and improve the Bird Strike Monitor
- Conduct performance tests that simulated live bird strikes with wires to determine the correlation between actual strikes and those recorded by the Bird Strike Monitor.

2.0 Methods

2.1. Overview of Bird Strike Monitor Design

The Bird Strike Monitor has two components:

- Monitors hung on conductors or ground wires.
- A ground station.

2.1.1. Monitors

The monitors detect bird strikes and measure their force, and then transmit these data to the ground station, which stores them for remote access. The basic parts of the monitor are an accelerometer, a microprocessor, a transceiver (two-way radio), and a battery pack enclosed in an aluminum housing that clamps onto the powerline (Figures 1 and 2).

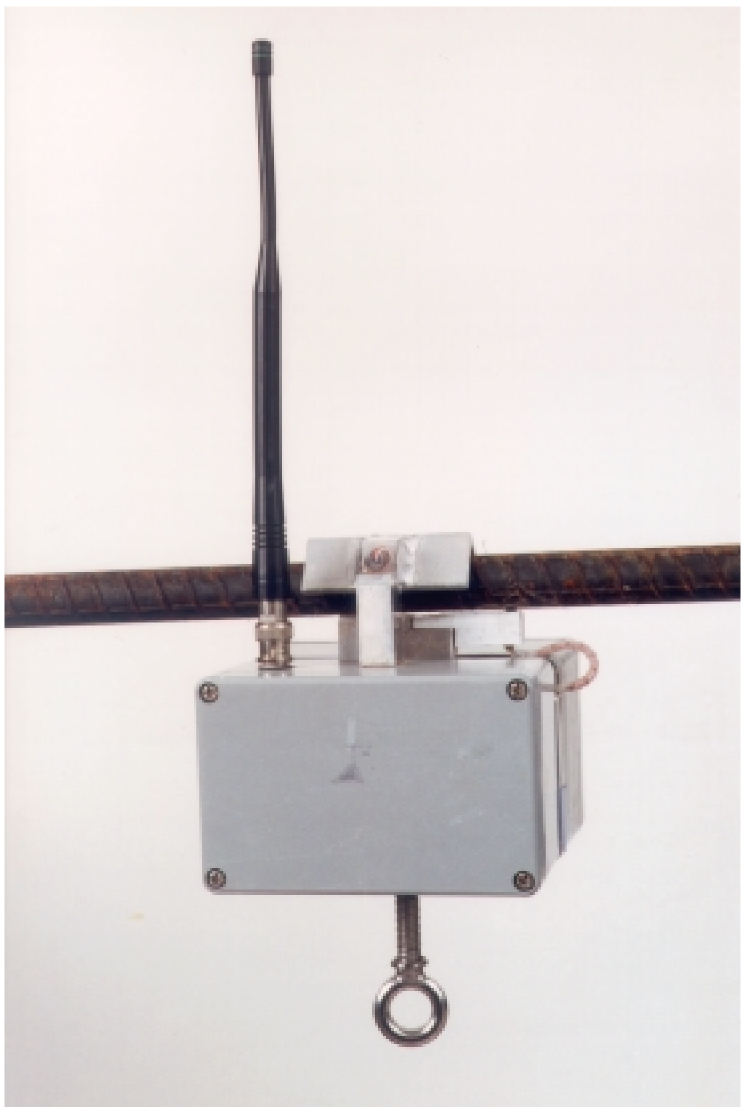

Figure 1. Bird Strike Monitor

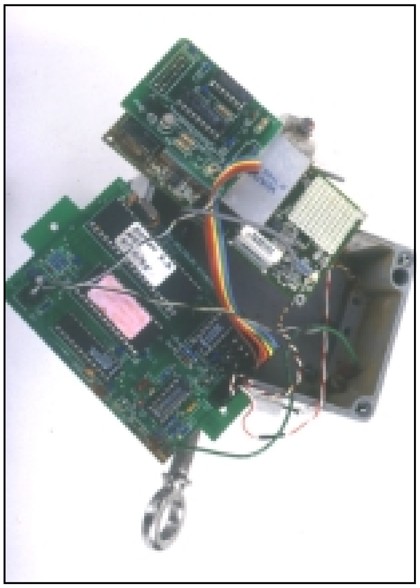

Figure 2. Bird Strike Monitor Components (clockwise from the top): Coprocessor board mounted on Proxim RXA300 radio. The gray wire in center foreground connects the radio to the antenna (not shown). Accelerometer (small gray cylinder on top mounted on outside of monitor. Stainless eye bolt for attaching clamp to conductor with hotstick. Processor board with Microchip PIC17C74 microprocessor. Note label indicating that Ver. 3.2 of the monitor software has been burned into this chip. Batteries are contained in a separate compartment on the opposite side of the monitor.

The microprocessor constantly measures accelerometer output. When an acceleration value exceeds the preset trigger value (5 Gs), about 2 seconds of data are taken and stored, including a short period before the trigger. (The 5 G value for the trigger was determined to be the lowest setting that would not result in excessive numbers of false triggers.) Upon completion of the sampling, the microprocessor sends the data to the transceiver, which broadcasts it to the ground station. The monitor unit‘s accelerometer is triggered only by vibration in the horizontal direction. This reduces the possibility of false triggers from wind-induced vibrations.

The transceiver used was a Proxim RXA300 spread spectrum radio. This radio operates in the 902 – 928 MHz frequency band. It uses frequency division multiplexing (a direct sequencing technology) to provide multiple software-selectable channels. Spread spectrum technology is a type of radio modulation technique that spreads a transmitted radio signal over a frequency band greater than that needed to simply send the data. Spread spectrum radios are designed to resist interference. Direct sequence spread spectrum spreads the signal over a wider frequency band for transmission, and the receiver reassembles the data. Fewer channels can be used. Table 1 shows the characteristics of these types of spread spectrum. A second spread spectrum technology, frequency hopping operates by transmitting at one frequency for a short time, then hopping to another, and so one. The transmitter and receiver must be synchronized so they are on the same frequency at the same time. If interference is found on one frequency, the data is retransmitted on a subsequent hop. Frequency hopping spread spectrum allows many channels to be used.

Table 1. Characteristics of two types of spread spectrum radios.

	Direct Sequence Spread Spectrum	Frequency Hopping Spread Spectrum
Transmission	Broadband Continuous Transmission	Narrowband At Any Instant, Discontinuous Transmission
Speed	Higher Data Transfer Rate, Larger Packets	Lower Data Transfer Rate
Data Integrity	Lower	Higher
Reliability	Can Fail To Maintain Communications In Adverse Conditions, When Interference At Receiver Exceeds Received Signal Power Even Slightly	Assures Maintenance Of Communications, But At Lower Speed
Interference	Avoids Interference By Spreading Energy Across Band	Hops Around Interfering Source
Power Consumption	Higher	Lower

The frequency division multiplexing (FDM) used by the Proxim radio divides the signal into multiple frequencies (sub channels) then combines them for transmission on a single channel. A circuit called a multiplexer accomplishes the division of the signal. Individual signals are separated out at the other end by a demultiplexer. The signal is sent at maximum speed at all times.

2.1.2. Ground Station

The ground station (Figure 3) has a transceiver, microprocessor, and modem. It stores data until it can be downloaded through a phone connection. The phone connection may be made using any standard modem and telecommunications program supporting Z-modem file transfer. In addition, a Windows program has been developed to access, download, and process data.

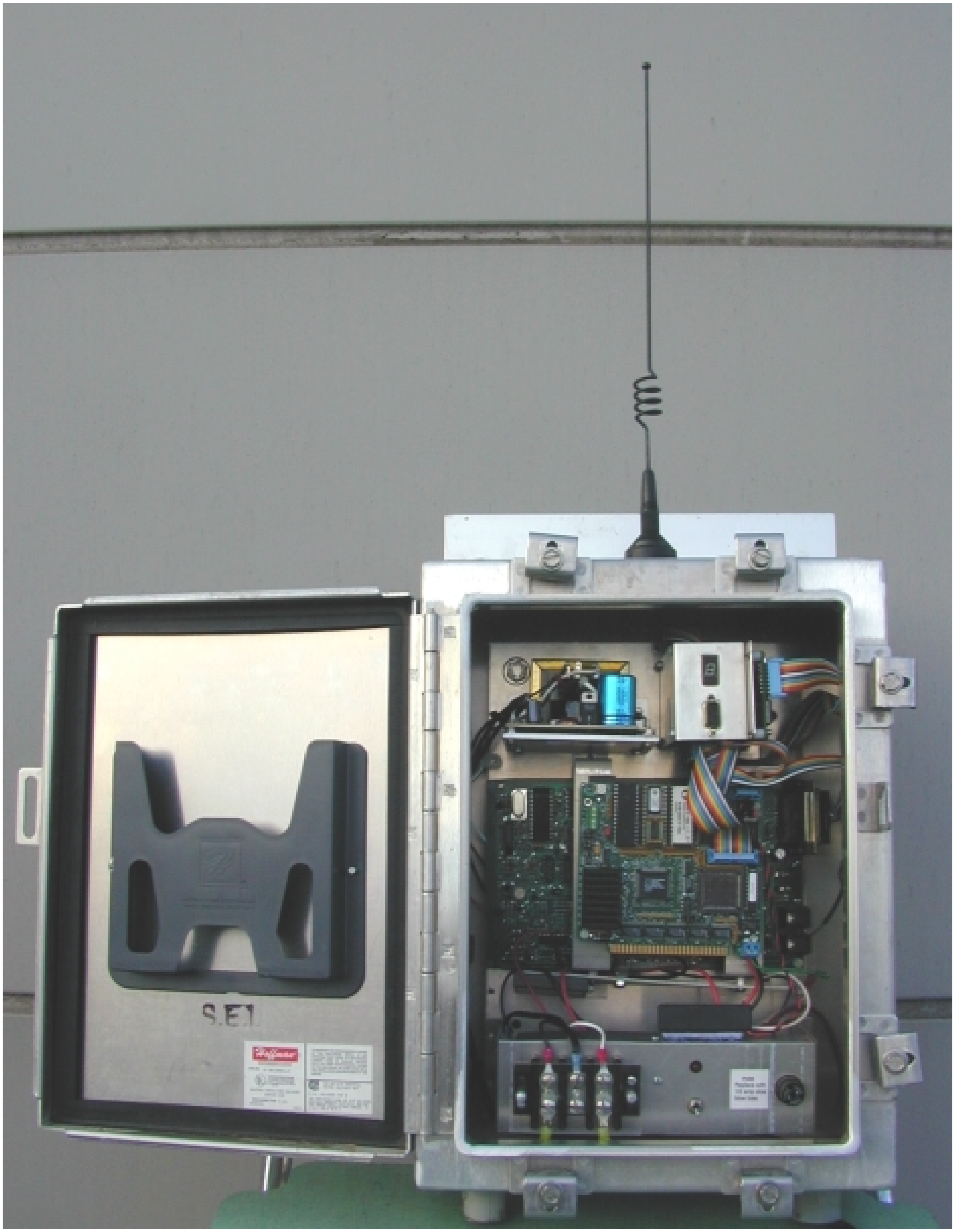

Figure 2. Monitor Ground Station

2.2. Design Improvement

The goal of this project was to produce a monitor that could be fabricated or manufactured by others. It was envisaged that several improvements would be made to the bird strike monitor. These included weatherproof housing, possible increase of the trigger level to eliminate false strikes, and debugging, installing, and testing improved control software, which had already been developed. There were also plans to migrate the ground station control program from DOS to Linux, and to make various improvements to the program.

2.3. Performance Testing

Pacific Gas and Electric Company's General Construction line men built a single conductor test line for the bird strike monitor at TES (Figure 4). We consulted with distribution engineers and linemen to determine the most typical spans, materials, and tensions. The test line was constructed to their specifications at a convenient height. The conductor is #4 ACSR, 300 feet in length, and tensioned by sag to specifications.

Figure 3. Installing Test Line

For testing, a monitor can be mounted at any point on the line. We placed the ground station, outside the laboratory building and connected it to an analog modem line and household current through a power converter. Data was accessed by dialing in with a computer through another analog modem line using a custom program, (BIRDSTK) on any simple communications program. An independently operated video camera was mounted on a tripod to capture strikes on film. Because the old battery packs had been taken out and thrown away in 1996, the monitors were powered from an external power supply, a 12-volt automobile battery, until we built new custom battery packs. The first set used sulfur dioxide lithium batteries. Later, a second set of custom battery packs was prepared from lithium thionyl chloride batteries, used in the original monitors, in an attempt to correct data transmission problems.

TES technicians constructed a bird cannon (Figure 5). It is a mechanical device designed to propel dead birds at velocities appropriate for testing (10 - 50 miles per hour). Accelerometers were placed in the pan of the cannon and on the line, and connected by cable to an HP 35670A dynamic signal analyzer to provide additional sample velocity checks. The cannon was mounted on the back of a pickup to allow easy positioning in relation to the test line.

Figure 4. Bird Cannon Ready to Fire

We used a beanbag--a one-pound package of dried beans wrapped in duct tape for preliminary testing. A cooperative hunter supplied dead ducks including green-wing teal, spoonbill, widgeon, and gadwall, ranging in weight from approximately 11 ounces to 1 pound, 13 ounces.

3.0 Outcomes

The goal of this project was to produce a monitor that could be fabricated or manufactured by others. The major outcomes were:

- We documented the design of the Bird Strike Monitor system.
- The Bird Strike Monitor as designed and tested did not produce consistently reliable data. We were unable to correlate the number of bird strikes recorded by the monitor with dead birds or their remains. This was contrary to the previous test at Klamath Falls. The primary problem was the drastically changed radio transmission environment in the 900 MHz range.

3.1. Design Improvement.

Since the Proxim radio was nearing the end of its commercial cycle and would soon be unattainable, we looked into replacing it. Replacement of the monitor radio with a newer model transceiver turned out to be a complex task. Not only would it involve new programming for the ground station, but would also require a complete redesign and reprogramming of the monitor and its circuit board, and possibly a redesign of the housing to accommodate it. This work was beyond the scope of this project.

Instead of redesigning the monitor, we decided to document the original design in enough detail to allow further development. Documentation had been hampered by the misplacement or loss of equipment and files in the confusion after Pacific Gas and Electric Company's R&D Department was eliminated. During this study original drawings and specifications were searched out, and explanations of the design gotten from the original designers. No plans were ever drawn for the ground station, so a contractor was hired to document it. This documentation (Appendices I though IV) should be sufficient to allow development to continue, should any support be found for it.

3.2 Performance Testing

3.2.1. Initial Test Attempts

Initial performance tests were started with the complete experimental setup -- bird cannon, external accelerometers, dynamic signal analyzer, ducks (thawed), technicians, and a vibration engineer. It soon became apparent that the system was not producing reliable data. Figure 6 shows a typical waveform produced by a bird strike on a line. The time axis is about two seconds. The Gs represent the acceleration back and forth in the horizontal plane as the wave travels down the wire. The second peak is the echo of the wave traveling back up the line. A strong lineman giving the line a hard smack with a hot stick might produce an impact force of 50 Gs. The maximum force generated by a large bird hitting the line while traveling fast is between 50 and 75Gs.

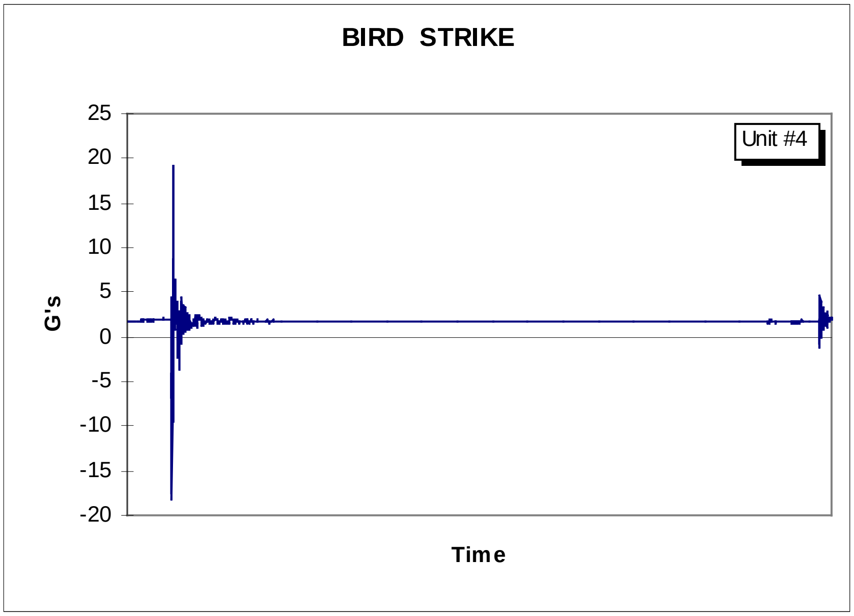

Figure 5. Typical Waveform Data Produced by the Bird Strike Monitor

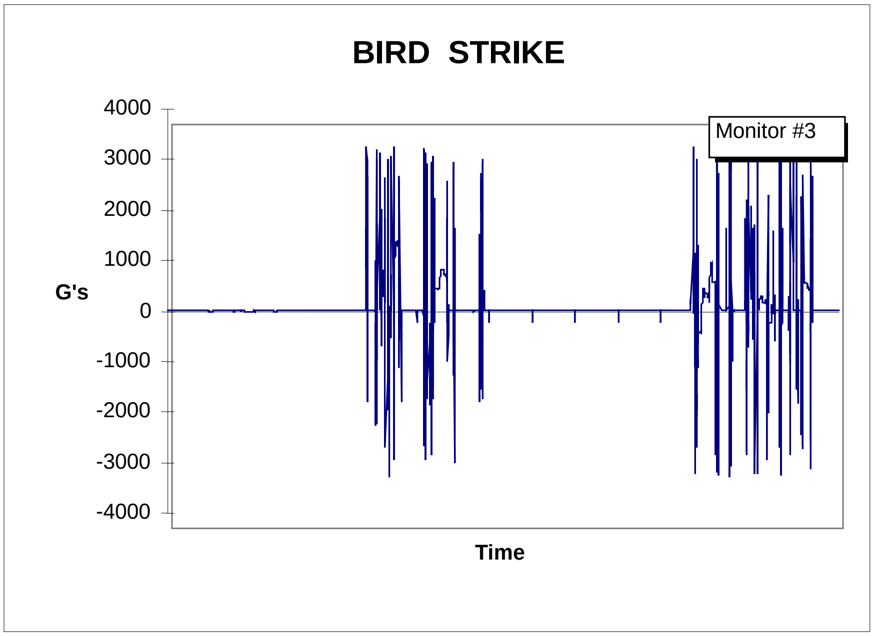

Figure 6. Waveform Produced by Corrupted Data

Comparison of Figure 6 with Figure 7, two typical graphs produced by corrupted data, shows the problem we encountered. A force of over 3,000 pounds was recorded, approximately two orders of magnitude greater than a bird could generate. When the scale of Figure 7 is expanded, it shows a reasonable waveform initially, but the last two-thirds of the data file is corrupt. The large peaks are spurious. A close examination of the data files in binary form shows that the corruption results from loss of data. Loss of a single bit can cause an effective reversal of the hi-byte lo-byte sequence, with the same effect as reversing units and tens digits. Small numbers turn into very large numbers.[1] During these initial tests only 25 percent of the data were usable. The rest showed corruption, or did not record files on the ground station.

We did not notice this form of data corruption during laboratory and field tests in 1995 and 1996. After much searching through old data files, two similar instances were found. One was during laboratory testing at TES, and the second during installation of the

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[1] Other characteristics of the spurious waveforms, such as the maximum of around 3200, and the regularly occurring hash marks, can also be explained by the effect of shifting bytes in the original data stream. See Appendices II and IV for more information

monitors at Klamath Falls. Although some spurious data was seen during the Klamath Falls test, it appeared to be the result of moisture infiltration into the monitors and produced different waveforms.

We tried a number of fixes to correct this problem. The test line was grounded to eliminate any effect of induced current from the recently installed 230 kV substation in TES's parking lot. Since the monitor was designed to work on energized lines, and performed well on them during tests, it was not surprising that this had no effect. Different configurations of monitor and ground station were tested. The connection between the ground station modem and remote computer was thoroughly checked out by a telecom technician using a breakout box. Hardware and power sources were checked, battery packs were installed in the monitors, and ground station software was checked out.

This troubleshooting lead us to suspect that the battery packs were deficient. At this time we finally uncovered an original drawing of the battery pack and discovered we had used a different type battery. The original battery had twice the energy density of the one we had installed. Because the transmitter power on the Proxim radio varies with power input from 4V to 10V, we suspected that it was not getting enough power to transmit properly.

Ten monitors with the new lithium thionyl chloride batteries were tested mechanically by shaking. The new batteries appeared to largely solve the problem., but some data were still corrupted or not transmitted successfully. This is not acceptable for a final product, but it could allow the performance testing to proceed. Unfortunately, the tests had not followed the tinkerer's dictum - - change only one thing at a time. They were conducted indoors due to incessant rain.

When the tests were moved outdoors results became less dependable. An initial day of testing with a beanbag in the cannon yielded about 70 percent good data. Unfortunately, the technician was having trouble aiming the cannon that day. On subsequent days results were highly variable, ranging from 55 to 85 percent good data. As a final disappointment, it proved impossible to record clean data while the extra accelerometers were attached to the line. We believe that the cables attaching the accelerometers to the terminal were acting as antennas, and retransmitting to the ground station.

3.2.2. Troubleshooting

At this point, we abandoned testing and concentrated on troubleshooting. Data corruption appeared to occur during transmission of data from the monitor to the ground station. When the ground station logs were examined, it was clear that the monitor picked up and attempted to send records from every strike. Not all data made it. Some was recorded with errors. If the data were too corrupt, it was not saved.

Four different actions were taken to discover the source of data corruption.

1) Two radios were returned to the manufacturer for testing. One was known to have problems, but the other had performed reasonably well. One radio showed a low power output, and the other a low carrier detect lock-up time. These problems made the radios more susceptible to interference, but should not have been severe enough at short distances to explain the high rate of data loss.

2) In June 2000 the original programmer of the ground station, Greg Herlein, became available and was contracted to check out the ground station. He fixed a loose antenna wire, and loaded a more recent version of the ground station software. The system performed perfectly at his laboratory in San Francisco's Cow Hollow. We then retested it TES. While a problem with long write times had been solved, data transmittal was still poor.

3) Pacific Gas and Electric Company’s Computer and Telecommunications Services conducted a radio interference survey at TES on the morning of June 20, 2000. Five monitors were checked during this survey. The survey showed that the monitors transmitted on Channel #1 in the 900 MHz band. Channel #1 is centered at 906 MHz with a bandwidth of 1.8 MHz. One monitor had a low transmit signal, and another transmitted a signal oscillating from 902 to 932 MHz, sweeping to 928 MHz and back to 932 MHz with full transmit signal spikes. Three put out strong regular signals at the appropriate delay times on Channel #1. Most significantly, the radio frequency interference test showed interference from the Moore Building (about 250 yards northeast of the test site) at 902 – 906 MHz. This interference increased between 8:30 a.m. and 10:00 a.m. In addition, three other sources of 900 MHz transmission were noted by their transmit signal spikes. These appeared to be frequency hopping spread spectrum transmission. One was strong enough to cause interference if it occurred simultaneously with a monitor transmission.

4) We searched for local sources of radio transmissions in the 900 MHz band. Numerous transmitters were identified near Pacific Gas and Electric Company’s San Ramon Laboratories (see Figure 8). There are two antennas on the roof of the four-story Moore Building, located 250 yards northeast of the test site. One belongs to GTE Mobilenet and transmits at 880 MHz and receives at 820 MHz. The second belongs to PacBell Wireless and transmits at 1900 MHz. There are seven Metricom® wireless LAN transmitters within a half-mile of the Pacific Gas and Electric Company’s San Ramon Laboratories. Two are within 350 yards of the test site,

although one of these is blocked by a hill. In addition, the Pacific Gas and Electric Company maintains a digital microware station at the Learning Center near TES.

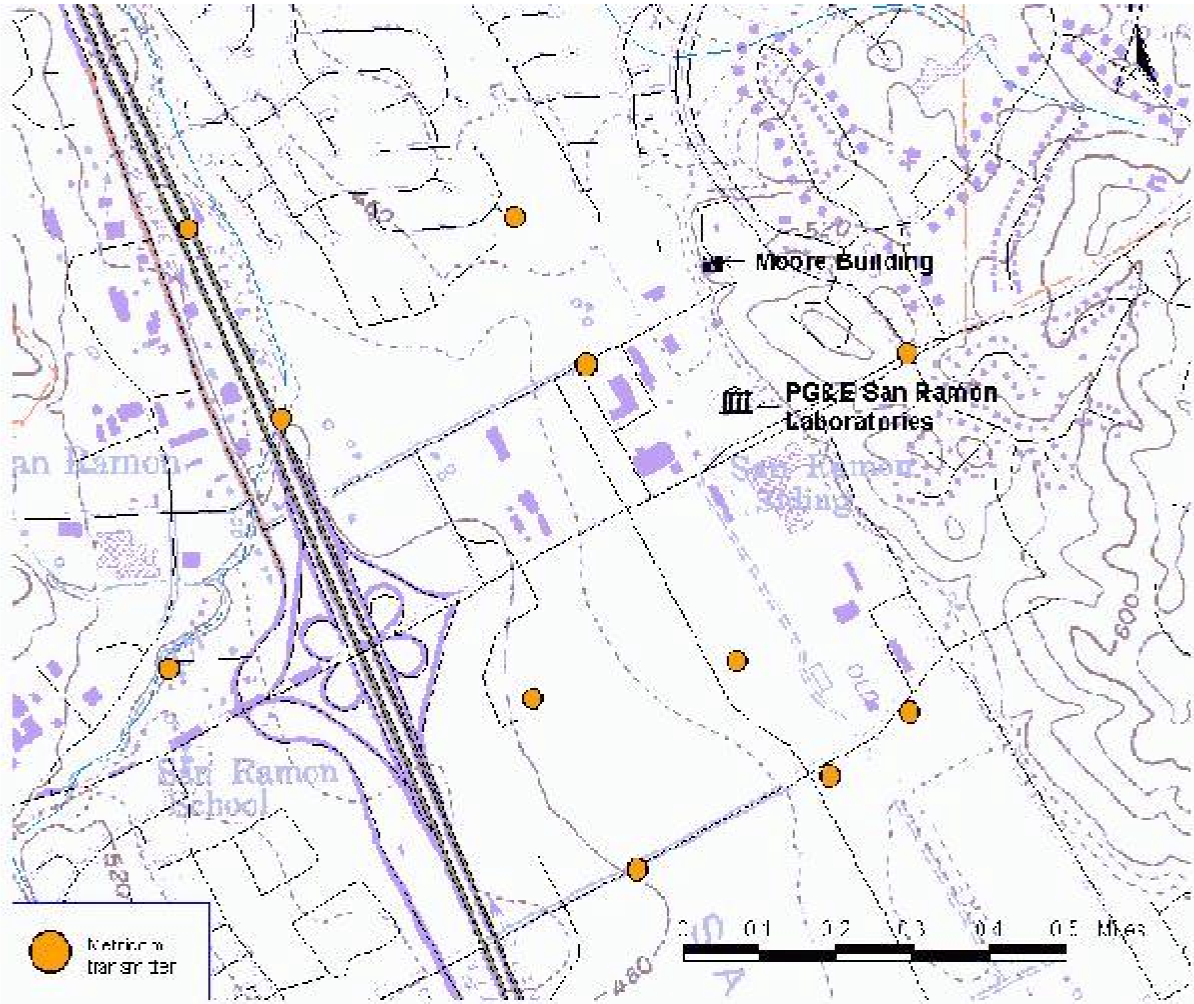

Figure 8. Metricom transmitter sites near the test site.

4.0 Discussion

The Federal Communications Commission (FCC) opened the 900 MHz band to license-free commercial use in 1985. It has also opened the 2.400 – 2.4835 GHz and 5.725 – 5.850 GHz bands to license-free operation. The license-free bands are sometimes called ISM (industrial, scientific, and medical – originally envisioned by the FCC as the users of this spectrum) or Part 15 (of Title 47 of the FCC Regulations). Today, devices operating in the 900 MHz band include wireless internet connections, cordless phones, baby monitors, wireless stereo or video devices, and wireless headsets. Cellular phones and paging systems operate near the 900 MHz band; and when these systems use high power they can also cause interference. Interference can also be caused by high-powered electrical equipment, or high power radar systems used in airports or by the military. To qualify for license-free operation, devices must observe certain limitations designed to reduce interference among users. Among other things, they cannot transmit at a power greater than a watt (although some government military users may transmit at up to 5 watts), and must use spread spectrum technologies. The manufacturer certifies devices in compliance with Part 15. Users who experience interference have little recourse

There are increasing concerns that the surge in use of the 902-928 MHz band is leading to saturation of the bandwidth, and deterioration of data transmission capability. Frequency-hopping technology can dramatically minimize these problems, but eventually can also be overwhelmed by sheer volume of interference. Manufacturers appear to be reluctant to acknowledge problems with crowding in the 900 MHz bandwidth. Little information is available in the standard media. However, several papers published on the internet document interference in this part of the spectrum. The first was a class project by two computer science graduate students at the University of California at Berkeley. (Amir and Balakrishnan, 1996) which evaluated the then-new Ricochet® system from Metricom®. Ricochet® provides a wide area wireless Internet access. It achieves coverage by a grid of radios on streetlights and utility poles. These pole-top radios route modem packets to a wired access point. Ricochet® uses frequency hopping spread spectrum across 160 channels in the 900 MHz band. Amir and Balakrishnan looked for interactions when Ricochet® was used near Lucent Technologies WaveLAN, another wireless internet access. They found that even light Metricom® traffic can seriously interfere with WaveLAN performance, while WaveLAN has much less effect on Ricochet®.

The second paper was by a group of WaveLAN users from Laramie, Wyoming (Glass, 1997). They compared the performance of WaveLAN in two cities on the same day: Scottsbluff, Nebraska, where Ricochet® has been deployed, and Cheyenne, Wyoming, which does have a Ricochet® installation. The number of packets successfully sent was 100 percent in Cheyenne, but only 12-20 percent in Scottsbluff. The two groups differ in their explanations for the degradation of the WaveLAN performance. WaveLAN uses a direct sequence CDMA spread spectrum technology, while Ricochet® is a frequency hopping spread spectrum system. Amir and Balakrishnan believe the difference is because Ricochet's technology produces a larger amount of energy in a narrow band at any one instant, while WaveLAN's broader band results in a lower energy per bit. Glass, however, believes that WaveLAN's direct sequence technology allows it to tolerate even intense interference in a narrow band. Thus a single frequency hopping transceiver would not unduly interfere with other transmitters. However, since Ricochet uses a grid of transmitters, they can generate sufficient interference to jam the

WaveLAN installation. Furthermore, the Ricochet units may be able to increase their transmission power (up to the maximum one watt) if the transmission fails, thus shouting over other transmissions in the 900 MHz band.

Ricochet has been installed in the San Ramon and Danville areas. Indeed, the company leases space on distribution poles and streetlights from the Pacific Gas and Electric Company The company has also installed grids in the San Francisco Bay Area, Seattle, and Washington, D.C., and is expanding rapidly into other cities.

During radio interference testing it appear that the intermittent spikes seen were from Metricom transmitters. The prolonged interference in Channel 1 of the 900 MHz band came from either the Pacbell Wireless or, more likely, from the GTE Mobilenet antenna on the Moore Building.

The increase in interference highlighted some weaknesses in the software. Although the Proxim radio is a transceiver, and can send and receive at both ends, the software does not take advantage of this. It does not look for a clear time to send. It uses a simple checksum error checking routine, so the ground station knows if there were errors in the data stream. This software was custom written by Pacific Gas and Electric Company technicians and contractors. They did not have time to implement these features, which were not needed in the interference free environment of five years ago.

There are several possible solutions to radio interference problem. The application could be moved to higher, less crowded frequencies. However, there are two problems with this. First of all, the higher frequencies, with shorter wavelengths, have less range. Secondly, with the exponential proliferation of wireless devices, it is only a matter of time before these regions of the spectrum also become crowded..

The current system could be made to work for a time by shifting the monitors' radio transmission to Channel #3 (912 MHz) from the crowded Channel #1. This would require replacement of the microprocessor chip in each monitor, and some modification of the ground station software. Alternatively, many areas in the United States do not have the density of radio transmitters present the Bay Area. The monitor could still work in these areas, particularly if radio interference surveys were done.

We do not recommend either course of action. The additional channels in the 900 MHz band will probably also become crowded soon, and wireless transmitters are spreading out from urban areas. A better course of action would be to redesign the system to eliminate problems caused by radio interference.

5.0 Conclusions and Recommendations

5.1. Conclusions

The project demonstrated that the current design of the Bird Strike Monitor is no longer functional in areas with significant radio traffic in the 900 MHz range. Our problems with it stem from the drastically changed transmission environment in the past five years. It seems that we could not have chosen a more hostile radio environment for testing the device than the TES grounds. Nevertheless, the system must be able to perform in hostile environments to be credible.

To produce a bird strike monitor that will reliably record bird strikes, the current system will have to redesigned and incorporate a new radio and new software. Software was not configured to optimize monitor transmission. Developing software that did would eliminate many of the problems. However this must be done in conjunction with changing the radio.

Existing design can only be used in areas where radio site surveys have shown that interference would not create a problem.

5.2. Recommendations

To encourage further development of the system, the following recommendations are offered:

Obtain recommendations from specialists in wireless data communication special applications on radio frequency bandwidth and technology for future radio selection.

- Depending on the radio chosen, develop software to take advantage of the technology's abilities to resist interference.
- Since the radio must be changed, the monitor's circuit board must be redesigned, and hardware modified. New waterproof housing is required, and can be designed to accommodate the new components.
- Upgrade the data collection method to make it Internet and pager-capable. The proposed system would be a Unix-based PC computer running the commercially available Red Hat Linux 5.2 operating system. This system would call the ground station as frequently as desired, and the software would conduct an automatic download of the ground station. If data was available for download, the software would email or page people on a warning list.
- Additional improvements can be made to the functionality of the system:
  - Upgrade the ground station hardware. By adding an up-to-date single board computer and flash-memory storage system, the existing ground station hardware would be replaced with more capable hardware and software. The ground station could automatically call the server to announce that a bird strike had occurred. It could transmit its data seconds after the sensor had activated. This feature could be quite helpful if it led to the discovery of a downed bird before the carcass was lost to predators.

- It would be useful to have a method of changing the monitor's trigger point short of burning in a ROM chip..PG&E05, Revision 2 07/21/00 1:15 PM 25

- Clean up minor bugs in the ground station software and the modem interface program. Once the necessary changes have been made to the system's design, it is critical that prototypes be thoroughly tested in the laboratory and the field.

5.3. Benefits to California The Bird Strike Monitor would benefit California electric ratepayers by providing an improved method of detecting bird collisions with overhead wires, allowing utilities to more easily identify spans in which mitigative measures are needed. It would also be very useful in evaluating the effectiveness of marking and other measures used to reduce bird collisions with wires. Since bird collisions can cause outages (mainly momentary outages), reducing bird strikes contributes to improved electric reliability as well as enhanced environmental quality (especially for the affected birds).

Although the Bird Strike Monitor Performance Testing Project fell short of its original goals, it identified a conflict between the technology and the recent proliferation of wireless devices. This conflict must be resolved to ensure reliable data collection. The funds provided by the California Energy Commission have allowed us to document the system sufficiently to allow development to continue.

6.0 References:

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Appendix I

Monitor Hardware Documentation

Appendix II
Monitor Software Documentation

Appendix III

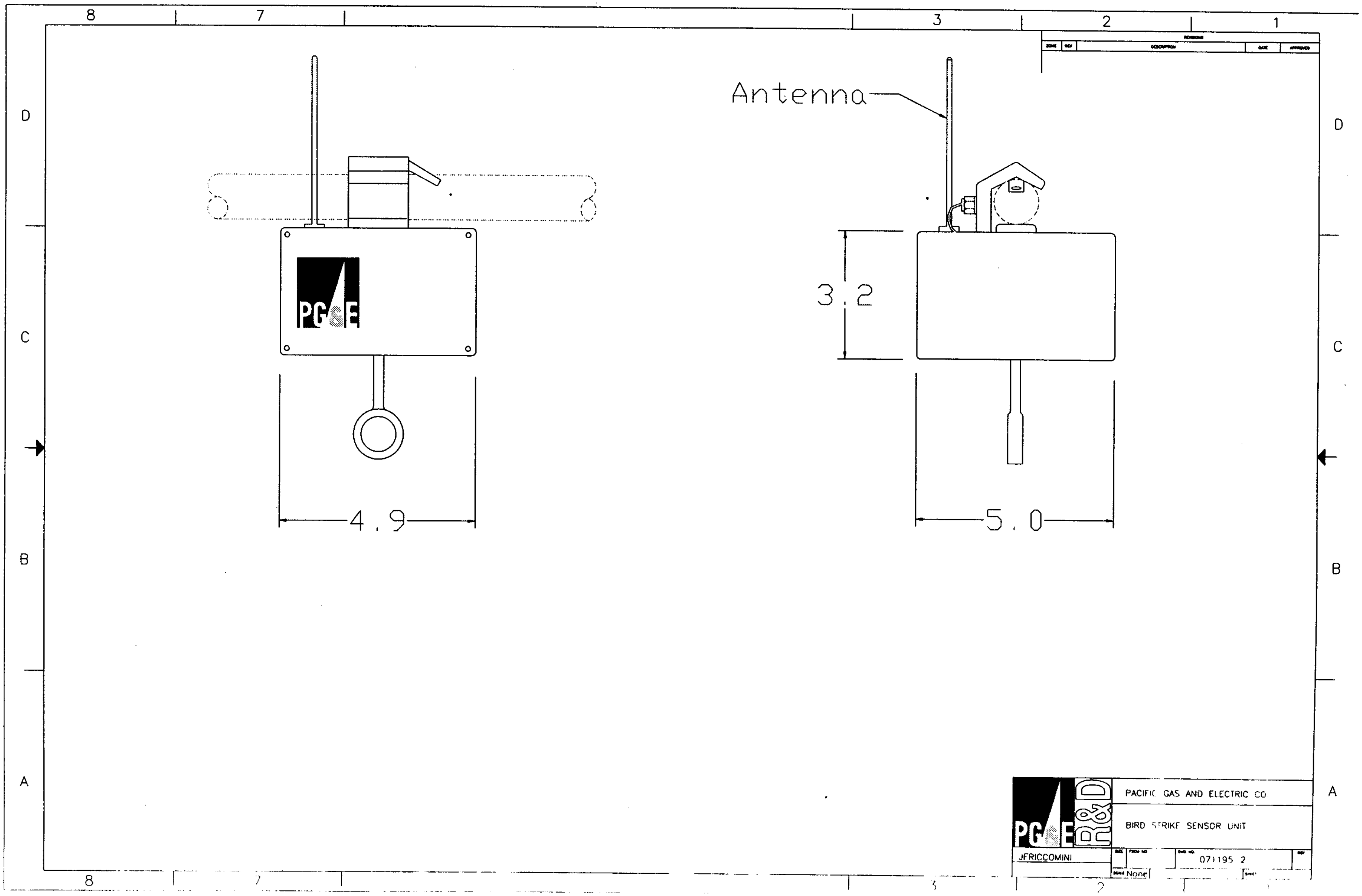
Ground Station Hardware Documentation

Appendix IV

Ground Station Software Documentation

Appendix I

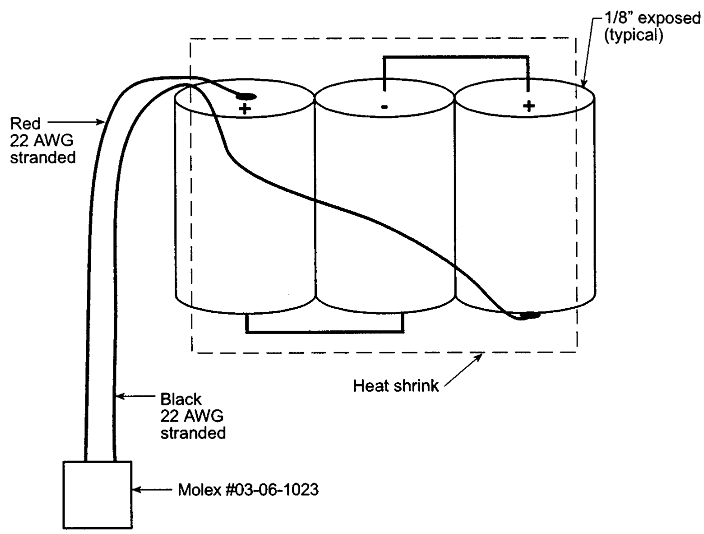
Monitor Hardware Documentation


Antenna
3.2
4.9
5.0
PACIFIC GAS AND ELECTRIC CO.
BIRD STRIKE SENSOR UNIT
JFRICCOMINI
071195 2
None

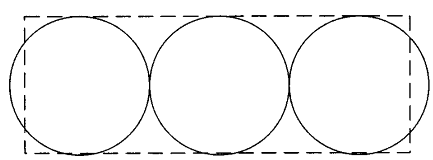
BIRDSTRIKE

BIRDSTRIKE MONITOR BILL OF MATERIALS				TO: Rodger Mayeda				
		Rev. 1	8-Aug-95					
ITEM	**QTY.**	**REFERENCE**	**PART**	**MFG.**	**MFG. PART #**	**VENDOR**	**VENDOR PART#**	**PRICE**
1	11	Cl,C3,C5,C8,C9,Cl3-C16,Cl 8,Cl9	1UF 63V MONO CERAMIC	PANASONIC	ECU-SlJl04KB	DIGIKEY	P4887-ND	0.13
2	1	C2	120PF	PANASONIC	ECC-F2Al2lJE	DIGIKEY	P4025-ND	0.02
3	1	C4	1UF 63V NON-POLAR	PHILLIPS	C3-30C10	NEWARK	14F3074	0.93
4	3	C6,C7,C10	100UF 10V	PANASONIC	ECE-AlAU101	DIGIKEY	P6214-ND	0.11
5	2	C11,C12	15PF 100V	PANASONIC	ECC-F2A 1 50JE	DIGIKEY	P1303PH-ND	0.02
6	1	C17	4.7NF	PANASONIC	ECQ-B1 H472JF	DIGIKEY	P4559-ND	0.05
7	1	D1	1N4148	DIODE INC.	1 N4148	DIGIKEY	1 N4148	0.04
8	1	J1	2 PIN CONNECTOR	MOLEX	705-43-0001	DIGIKEY	WM4800	0.57
9	1	J2	6 PIN CONNECTOR	MOLEX	705-43-0005	DIGIKEY	WM4804	0.83
10	1	J3	5 PIN CONNECTOR	MOLEX	705-43-0004	DIGIKEY	WM4803	0.77
11	5	L1-5	FERRITE BEAD	PANASONIC	EXC-ELSR35S	DIGIKEY	P9821BK-ND	0.08
12	1	Q1	J505 IN5297	SILICONIX MOT	IN5297	NEWARK	IN5297	
13	1	Q2	VP0300L	SILICONIX			299138	
14	1	R1	10 MEG 1%	YAGEO	MF-25	JAMECO	10MEGX-ND	0.02
15	2	R2,R3	332K 1%	YAGEO	MF-25	JAMECO	332KX-ND 30883	0.02
16	3	R4,R5,R7	1 MEG 1%	YAGEO	MF-25	DIGIKEY	10MEGX-ND	0.02
17	1	R6	3.32MEG 1%	YAGEO	MF-25	DIGIKEY	3.32MEGX-ND	0.02
18	2	R8,R9	10K 1%	YAGEO	MF-25	DIGIKEY	10KX-ND	0.02
19	1	U1	PIC16C74	MICROCHIP	PIC16C74-04P	BELL IND	PIC16C74-048	
20	1	U2	CD4051BCN	NATIONAL	CD4051BCN	DIGIKEY	CD4051 BCN-ND	0.75
21	1	U3	HM6264	NEC	HM6264LP-10	JAMECO	42884	3.19
22	1	U4	MAX191BCNG	MAXIM	MAX 191 BCNG	DIGIKEY	MAX191BCNG-ND	19.55
23	1	U5	LMC660CN	NATIONAL	LMC660CN	DIGIKEY	LMC660CN-ND	3.63
24	1	U6	LM2936Z-5.0	NATIONAL	LM2936Z-5.0	DIGIKEY	LM2936Z-5.0-ND	3.37
25	1	U7	LM35DZ	NATIONAL	LM35DZ	DIGIKEY	LM35DZ	2.49
26	1	Y1	2MHZ CRYSTAL	CTS	CTX068	DIGIKEY	CTX068-ND	3.60
27	1	PRINTED CIRCUIT BOARD FAB	BIRDSTRIKE PCB	TC CIRCUITS	30-6000-0	TC CIRCUITS		
MATING PARTS FOR CONNECTORS ON PCB								
	1	J1	2 PIN	MOLEX	50-57-9002	DIGIKEY	WM2800	0.34
	1	J2	6 PIN	MOLEX	50-57-9006	DIGIKEY	WM2804	0.51
	1	J3	5 PIN	MOLEX	50-57-9005	DIGIKEY	WM2803	0.48
		PINS FOR CONNECTORS	PINS FOR CONNECTORS	MOLEX	16-02-0102		WM2510	0.07

BIRDSTRIKE MONITOR BILL OF MATERIALS (MISC PARTS)								
		Rev. 1	**17-Aug-95**					
ITEM	**QTY.**	**REFERENCE**	**PART**	**MFG.**	**MFG. PART #**	**VENDOR**	**VENDOR PART#**	**PRICE**
1	2	Circuit/Battery Enclosure	Aluminum Type 4X	Hoffman	C-CA1286	ROSE ELEC		
2	1	Battery Pack (3 –D cell lithium)		Hawker Energy		ROSE ELECT		58.00
3	1	Battery Connector	Plug	Molex	3/6/2003	DIGIKEY	WM1220-ND	0.31
4	1	Battery Connector	Receptacle	Molex	03-06-1023	DIGIKEY	WM1230-ND	0.33
5	2	Pins w/ solder tail	Male	Molex	02-06-7103	DIGIKEY	WM1004-ND	0.16
6	2	Pins w/ solder tail	Female	Molex	02-06-7103	DIGIKEY	WM1005-ND	0.16
7	2	Stand-Off	6-32/.5 inch					
8	1	Radio	Radio	Proxim	RXA300	PROXIM		395.00
9	1	Accelerometer		Piezotronics	B35B17	PIEZOTRONICS	B353B17	395.00
10	1	Fuse	Fuse 1 amp	Little Fuse		DIGIKEY	F826-ND	0.71
11	1	Clamp Assembly						
12	1	Stainless Eye Bolt						
13	1	Custom Box Assembly						



Side View



Top View

Notes:

1. 3 - externacell lithium thionyl chloride batteries (T20/42) in series
2. Exposed pigtail - 6"

Bird Strike Monitor Battery Pack
3 - "D" cell lithium thionyl chloride batteries

Birdstrike Monitor Hardware Description
Analog and Digital Circuit Card
Mike Yee
September 5, 1995 Rev. 1

The birdstrike monitor is intended to be a data-logging device used to initially analyze acceleration information of a power line. The Birdstrike Monitor has 4 basic parts: Accelerometer and housing, Analog and Digital Circuit Card, Transmitter, and Battery. This document describes the Circuit Card.

Overview:

The birdstrike monitor circuit board (PCB) is intended to constantly monitor the acceleration output of an acceleration sensor. On a qualified acceleration signal, the signal is digitized and temporarily stored in memory. The temperature of the power line is also measured after a qualified acceleration signal. Occasionally the state of the battery is checked.

Technical Description:

A 10 VDC un-regulated power supply is created by the battery power supply. The power is routed to the PCB via. connector J1.

J1 - Power Connector

Pin	Name
I	Gnd
2	+10 VDC

A 5 VDC regulated power supply is derived from the +10 VDC supply with U6 (LM2936Z-5.0), a low power voltage regulator. C5-8 stabilizes the regulator.

J2 - Transmitter Connector

Pin	Name
1	+5 VDC
2	Gad
3	RX
4	TX
5	RE2
6	* N.C.

The signal transducers (accelerometer, temperature) are routed to the PCB via connector J3.

J3 - Transducers Connector

Pin	Name
1	Accel. Out
2	Accel. Gnd
3	+5 VDC
4	Temp. Out

5	Temp. Gnd.

Q1 – (J505) is a constant current diode which is what the accelerometer requires for functionality. The output of the accelerometer is high impedance.
U5D - (LMC7660) is a low, power buffer.

* R21, Cx - A.C. couples the acceleration signal to the bias restoration circuit. The amplitude of the acceleration signal is attenuated by %50 and the D.C. bias is set to l/2 full scale of the ADC (2.048V). The acceleration signal at the ADC is 10. The low pass frequency of this point is 0.002Hz, the high pass frequency is 200Hz. U5C is the output buffer of the bias restoration circuit. U5B is the integrator of the bias restoration circuit. R4-5 creates the reference of 2.048V. C3, C9-10 stabilizes the reference voltages.

R6-7 form a low current voltage divider so the battery status can be measured. The output of this divider is .2326Vout/Vbat.

The temperature output is l0mV/degree C.

The 3 signals are multiplexed by U2 (CD4051).

CD4051 Control

B (Pin 10)	(A) Pin 11	Selected Signal
0	0	Accel.
0	1	Temp.
1	0	Battery

U5A buffers the output of the multiplexer into the ADC (U4).

U4 is the system ADC (MAX191). The ADC is controlled by micro-controller U1 (PIC16C74). The control lines from the micro-controller to the ADC are handled by the RA bus lines RA1-5. The data lines from the ADC are connected to micro-controller bus RB. The ADC converts the signals in uni-polar mode.

U3 (HM6264) is a 2K x 8 CMOS RAM which is used to temporarily store data. The data lines use micro-controller bus RD which is the same as the ADC. The address lines use micro-controller bus RD and part of RC.

The micro-controller is run from a 2 MHz crystal (Y1). D1, R8-9, C18 form a power up reset circuit.

(* Changes are reflected in further revisions.)

Rev. 2 Amendment:

Changes:

1. R4 is connected to REFADJ (PIN6, U4) instead of VREF (PIN6, U4). C9, CIO are deleted.

2. R2 was 332K now 1k.

3. R3 was 332K now lmeg.

4. R1 was 10meg now lmeg.

5. R4 was 1meg now 174K.

6. Cx was 100UF Al electrolytic is now 1UF tantalum.

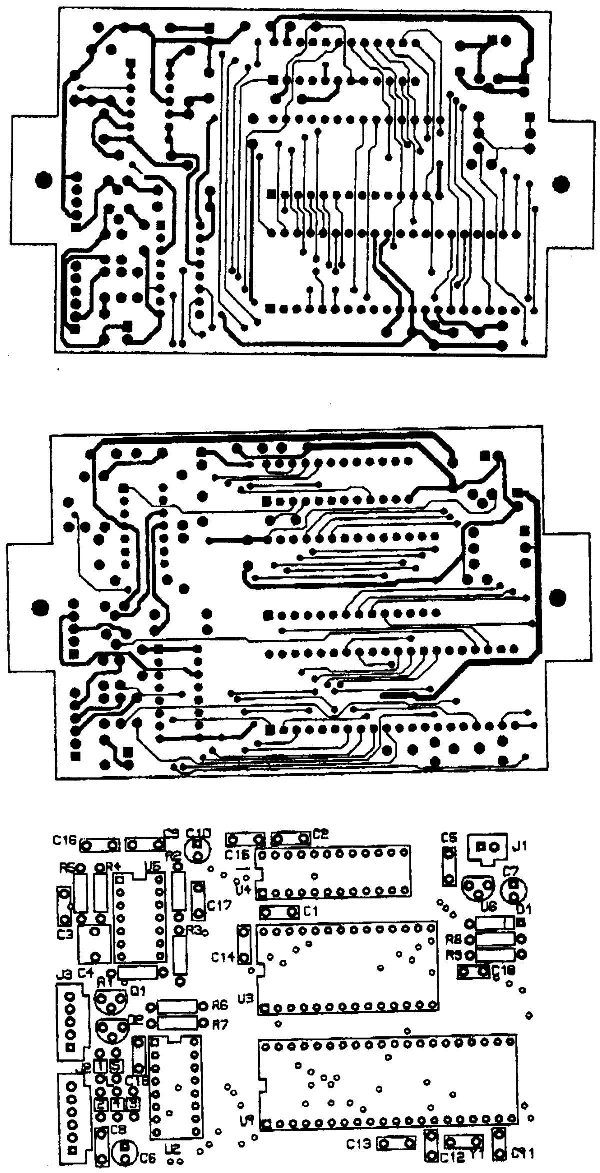
7. Transmitter interface board is added to program transmitter and control the power to the transmitter.

8. Q2 S-D arc wired across.

9. 2 MHz clock is added to pin 6 of J2.

10. C17 was 4.7nF is now 0.1 uF.

The bias restorer-summing node does not attenuate the signal in Rev. 2. The low pass comer frequency is .2Hz. The high pass comer is now 1.6 kHz. The acceleration signal is 10mV/G at the ADC.



Analog and Digital Circuit Card

Appendix II

Monitor Software Documentation

Bird Strike Monitor Software

Bird Strike Monitor – Version 3.2

(c) Pacific Gas and Electric Co. – R and D Lab
September 20, 1995 – All Rights Reserved

This program will control a Microchip PIC16C74 microprocessor to monitor an accelerometer attached to a distribution line. The accelerometer will be used to monitor unusual vibrations on the line (bird strikes). The processor will control a 12 A/D converter mixed to an accelerometer and a temperature sensor. Conversions will be constant at 1 kHz. This data will be stored in a 4096 word buffer. Upon detection of a valid trigger, the processor will take an additional 3840 words of data. This data will then be sent to a ground station at 19.2 kbaud. The 4096 data words will be followed by 1 word of temperature data. It is assumed that he calibration range of the accelerometer will be +/- 256 g's, or 8 bits/g.

The 16C74 is being used because of the number of I/O ports, 16 bit interrupt timer, and uart available on the chip.

```
Processor oscillator frequency =    2.0 MHz
Instruction cycle frequency =       0.5 MHz
Instruction cycle time =              2 uSec
```

Notes:

Version 2.0 – substantial change between ver 1.0 and 2.0. Ver 1.0 used a 16C71 processor with an 8 bit A/D and was interrupt driven and therefore didn't allow for any pretriggering. Version 2.0 uses a 16C74 processor that will constantly monitor the accelerometer.

Version 3.0 – Will be programmed in 'C' rather than Microchip assembler.

7/30/95 – Processor oscillator frequency chagned to 2.0 MHz in order to reduce the operating current. At this frequency, 500 instruction steps are allowed between 1 kHz sample rates and 19,200 baud is still achievable with –7% error.

8/22/95 = Parity is odd

Version 3.1 – 9/9/95; Add interface to coprocessor board (PIC16C61). Operation of the coprocessor board will be transparent to the main board. The main board will signal the coprocessor board via PORTC.7 redefined as ext_irq. This connection is made through pin 3 of J2 on the main board, and pin 3 J1 on the coprocessor board. On reception of the IRQ from the main board, the coprocessor board will raise a line defined as "hndshk" (PORTB.1) hi. This connection is made through pin 5 J1 on the coprocessor board, and pin 5 J2 on the main board. The hndshk line is raised hi after the coprocessor board programs the transmitter with the proper synthesizer frequency. Once the hndshk line is raised hi, the main board may begin normal transmission through its TX port (PORTC.6). Connection to the coprocessor board of the TX line is through pin 4 of J2 on the main board, and pin 4 J1 of the coprocessor board. After the main processor board is finished transmitting the data, it will lower the IRQ line (IRQ is lo to hi transition on the coprocessor board). The coprocessor board will then shut the transmitter down and return to sleep mode.

9/12/95 – ‘ff’ will be used as the delimiter between data pages (512 bytes).

9/18/95 – ‘aaaa’ will be used as a delimiter at the beginning of a transmission. The delimiter will be followed by a typed code as follows:

    01 = test packet
    02 = heartbeat
    04 = data packet

Following the type code will be the data or heartbeat packets.

9/19/95 – Data burst on power-up is suppressed, heartbeat packet is sent instead. Data will be sent at 9600 baud.

Version 3.2

9/21/95 – Fixes the battery droop after transmission by adding a delay after transmission. This will allow the analog circuitry time to restabilize after the end of a transmission. Also changes will be made to increase the sensitivity of the triggering circuitry through software and decrease the interruptions to the tick counter.

Since there will be 12 monitors on 4 spans (3 monitors/span), the placement of the numbered monitors should be as follows:

Span 1 – 00, 04, 08
Span 2 – 01, 05, 09
Span 3 – 02, 06, 10
Span 4 – 03, 07, 11

This allows for the following time delay before transmission in seconds:

Span 1 – 00, 12, 24
Span 2 – 03, 15, 27
Span 3 – 06, 18, 30
Span 4 – 09, 21, 33

9/29/95 – This version burned into microprocessors

Bird Strike Monitor Co-Processor – Version 1.0

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August 29, 1995 – All Rights Reserved

This program will control a Microchip PIC16C61 microprocessor. On IRQ from the main Bird Strike Monitor board, the PIC16C61 will program the frequency synthesizer of the Proxim RXA Spread Spectrum Radio. Additionally, it will power the radio up from its low power STANDBY mode. After completion of that sequence, it will inform the main board that the radio is ready to transmit. The main board will then transmit 8k of data at 19.2 kbaud, 8 bits, odd parity and one stop bit. After completion of the data transmission, the main board will inform the co-processor board that data transmission is complete. The co-processor board will then shut the radio down in a specified sequence and return the radio to STANDBY mode. The co-processor board will then inform the main board that the radio is in STANDBY mode, and then go into a Sleep stat (low power mode), and wait for the next IRQ from the main board.

Notes:

8/29/95 – The co-processor board is necessary because the Proxim RXA radio needs to be reprogrammed after coming up out of STANDBY mode. This requires more lines than are available from the main processor board.

Appendix III

Ground Station Hardware Documentation

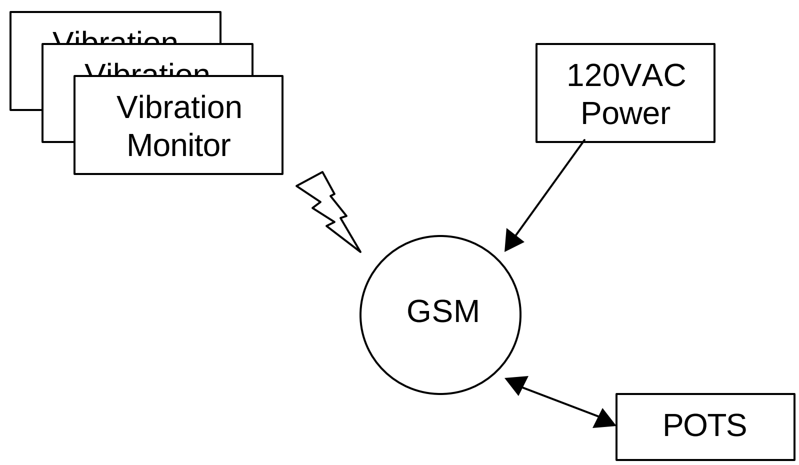
Bird Strike Monitor Ground Station

Hardware Documentation

Prepared by:
Endecon Engineering
2500 Old Crow Canyon #220, San Ramon, CA, 94583
925-552-1330 info@endecon.com

1. Introduction

Pacific Gas & Electric Company's Research and Development Department developed the Bird Strike Monitor system to record power line vibration profiles that may be indicative of bird collisions with these lines. This system consists of between one and thirty compact battery-powered vibration sensors equipped with digital radio transmitters and a single ground station to receive the transmitted data. This document describes the hardware design of the Ground Station Monitor (GSM), which is responsible for recording the transmitted data and providing that data on demand through a telephone modem connection (POTS or "plain old telephone service") to research personnel located offsite.



Due to the shutdown of PG&E's R&D department in the late 1990s, documentation of the GSM was not completed. Endecon Engineering was enlisted to produce this documentation package primarily by examining the prototype GSM and the component documentation that had been retained. In addition, former R&D technicians were available to answer a few questions.

A brief description of the major components has been generated along with some discussion of possible or necessary changes to be made if additional GSM were to be fabricated. Following the description of the device, appendices include a bill of materials, drawings and digital images of the actual prototype device.

Note that the design of this device is not optimized for mass production, since it is intended as a research tool.

2. Major Components

The major hardware components of the GSM are categorized in Figure 1 as power supply, computation, telephone communication, radio and status communication, and packaging.

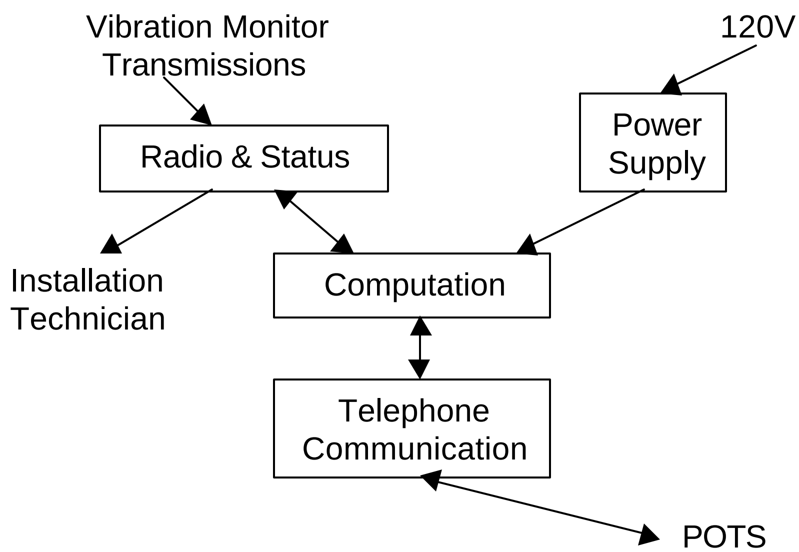


Figure 1 GSM Logical Component Relationships

The diagram in Figure 2 names the components shown in the photograph (Drawing 381.01.01.M002A, Backplane Assembly in Section 4 Drawings). External connections are the 120V Hot, Neutral and Ground connected to the terminal block on the Power Interface Assembly, and a standard RJ-11 telephone connector to the right side of the modem. Note that, as found, the lead-acid battery had been removed and the power supply bypassed with power from a laboratory power supply connected to the outputs of the GSM power supply.

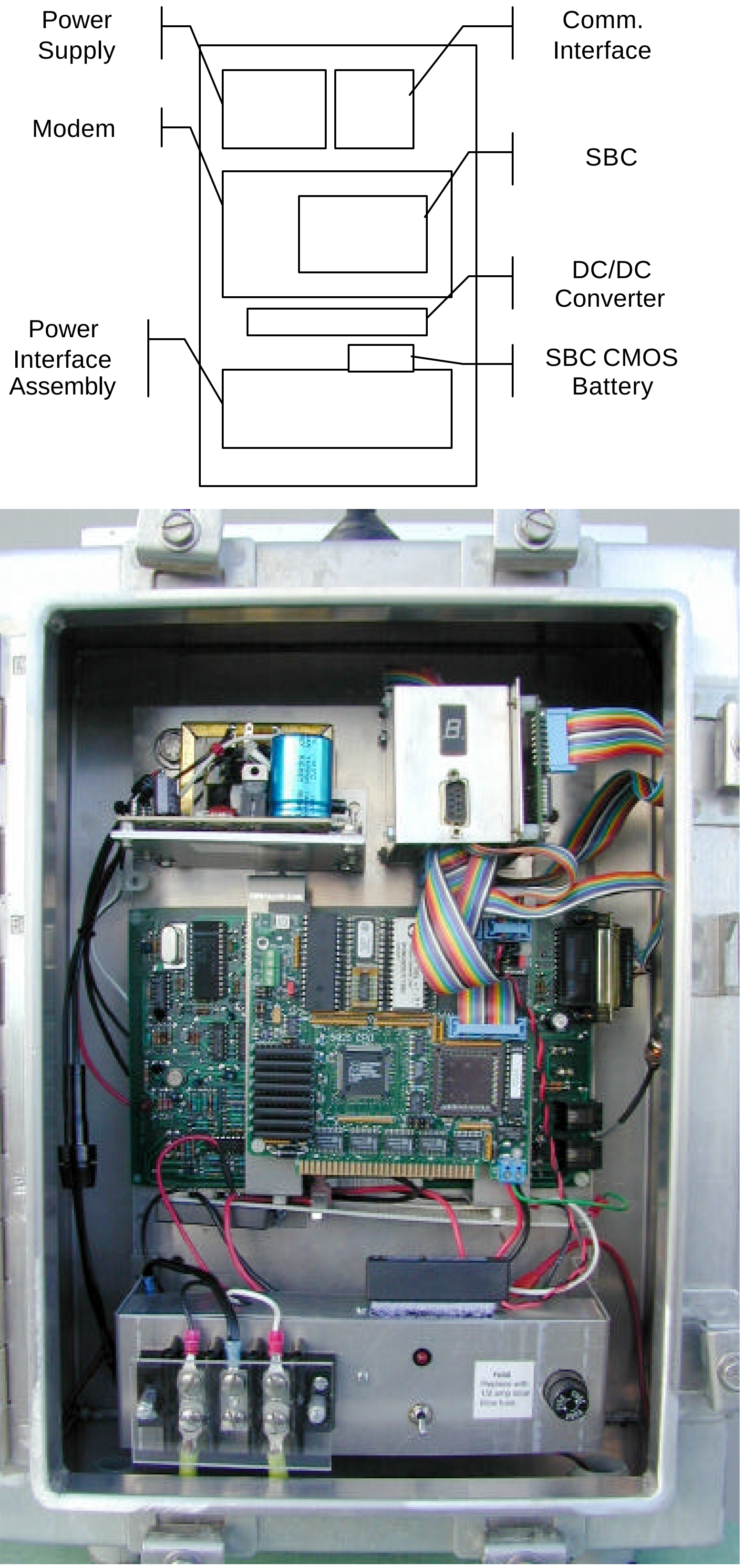


Figure 2 Backplane Assembly

Power Supply

The GSM power supply system transforms 120VAC line power into 5VDC power for the computation and radio communication elements. The Power Supply System includes the Power Interface Assembly, the power supply, and the DC/DC Converter. The Power Interface Assembly contains a terminal block for landing external ac power conductors, a power switch, a fuse holder, and an LED indicator for SBC power, Ac power is first converted to 12VDC so that a 12V gel-cell battery can keep the system operating during a brief power outage. The battery should be installed under the terminal block bracket and connected to spade lugs mounted next to the 12VDC to 5VDC converter on perforated blank circuit board. (The battery is no longer installed so it is not clear at this point whether additional brackets were used for this during field tests).

A switching power supply with remote voltage sensing is used to generate 12Vdc at the output of a blocking diode by feeding back the sense signal from that point. This voltage floats a gel-cell battery and supplies a dc-dc converter that supplies 5Vdc to the computation component. Fusing and a power switch are connected in the AC line to the switching power supply, and a 5V indicator LED is used to indicate when the SBC is powered, since turning off the switch simply reverts to battery power.

Computation

An IBM-compatible single-board computer (SBC) performs computation in this design. A flash-ram device serves as boot media so no moving parts are required. Documentation for the function of the software and user interaction with the GSM is described in the Birdstrike Monitor Ground Station Documentation.

Telephone Communication

Communication with remote analysts is handled by a line-powered 1200-baud modem. This modem draws power only from the telephone line, thus minimizing power requirements when the system must operate using only the gel-cell battery. While this communication rate is woefully out-of-date, the communication function performed by the device is standard, so replacement with current technology should be straightforward. Considerations for such modification include power source (preferably line power); mounting arrangement (new holes in the backplane); and minor reprogramming of the SBC software.

Radio and Status Communication

This component is really an assembly of components: a digital radio with antenna, a 7-segment LED display, and a custom-built interface circuit board to connect the radio and display to the SBC.

The digital radio included in this design, used to communicate with the vibration monitors, is no longer produced. While replacement functionality exists, the hardware control signals, connector pin layouts, mechanical layout, and software interaction are all different from the existing radio. The choice of radio is also strongly coupled to the design of the vibration monitors, which have stringent power and mechanical design constraints.

Connection of the radio is effected through a custom circuit designed to couple the radio interface with the SBC serial port, parallel port, and keyboard connector through standard ribbon cables. A TTL-to-RS232 signal translation is made to allow reception of serial data from the radio through the SBC serial port, and radio control signals are activated using data lines in the SBC parallel port.. This same circuit board includes an interface for displaying up to 8 GSM operating states through a single-digit 7-segment LED display. A final circuit function is a hardware watchdog timer wired to the SBC reset input through the keypad connector. All power for these functions are derived from the 5V power provided from the SBC through the keypad connector.

The schematic included in this package was generated by reverse-engineering the circuit board, since the schematic used for the original design work was missing.

Engineering changes made during the prototype development to the radio interface circuit on the circuit board included gluing a quad NAND-gate chip to the bottom as well as inclusion of several additional capacitors for power filtering. Since this radio is effectively unavailable for further GSM development, the interface would need to be redesigned for a new radio. For this reason, no layout is included in this documentation.

Packaging

A standard 16”x12”x6” NEMA4 enclosure was used to package the components. Four L-cross-section aluminum pieces were used to adapt the box for mounting with lag screws to a wood pole.

A standard cell-phone antenna was installed to receive the radio transmissions from the vibration sensors.

3. Suggested Modifications

The next implementation of the GSM should be able to re-use design concepts implemented in this design to good effect. For example, the use of an off-the-shelf PC-compatible single-board computer reduces hardware design and documentation efforts considerably, and the use of battery backup is fairly straightforward and functional.

Unfortunately, the accelerated rate of technology change has taken its toll in a few areas. The radio should be replaced with another model in current production, and an error-checking reliable communication mode should be implemented. Also, the modem used in this design is no longer in production, though they are still available in used condition. While the line-powered feature of the UDS modem used in this design does not appear to be available in current designs, there is the Star-Comm line of low power modems available from Arc Electronics that provides up to 33.6kbps speeds. Fortunately, both the modem hardware and software interfaces have not changed significantly as new models have appeared.

From the hardware perspective, communications options with new radios appear to be improved. For example, the Hummingbird 902 by Xetron includes models with an RS-232 interface that should alleviate the hardware interfacing requirements. However, the software interfacing requirements are considerably different than those for the older RXA-300, so some software changes will be required in order to accommodate the new radio.

Once the radio has been replaced, an obvious question is whether its remaining functions (status feedback, watchdog) could be provided without custom hardware. Most PC-compatible single-board computers include an onboard hardware watchdog function. Off-the-shelf parallel port displays are available as well (Octagon LCD4x40) with rather more functionality and only a little more power consumption than the existing LED display.

While the Octagon 5025 Single Board Computer is no longer available, the Octagon 5025A is an equivalent upgrade model, and if a performance improvement is desired (to support Internet data accessibility, for example) then there are numerous upgrade options from Octagon or competitors such as Advantech. Such a change would have a minor impact on interconnect wiring (connectors on SBCs are not necessarily compatible), mechanical design (hole placement and standoff size), software configuration management (procedures to initialize the SBC with the GSM software), and watchdog timer programming.

Appendix A. Bill Of Materials

The bill of materials (BOM) is organized as a hierarchy with the GSM divided into subassemblies consisting of one or more items, and some of those subassemblies are further subdivided. The "Component" column identifies the assembly while the "Part of" column identifies which larger assembly the component is part of. When an assembly has more than one part, its item number distinguishes each part from the other. The reference column indicates drawing numbers or schematic component numbers on schematics. List prices for major items, where available, are included.

The list below presents brief descriptions of the key values used in the Component column of the BOM, indented according to their assembly dependence.

- gsm - Ground Station Monitor
  - dcps - DC Power Supply
  - cia1 - Communications Interface Adapter
    - pcb - Printed Circuit Board
    - radio - Radio
    - commbrktA - PCB Bracket
    - commbrktB - Radio Bracket
  - ant - Radio Antenna
  - modem - Telephone Modem
  - sbc - Single Board Computer
  - dcdc - Dc-dc Power Converter
  - box - GSM Enclosure
  - pwrassy - Power Assembly
    - pwrassyparts - Parts

Table 1 Bill of Materials

Component	Part of	Item	Qty	Unit	Reference	Description	Mfr	Mfr Model	Vendor	Vendor Model	(Price)
gsm		1	1	ea	381.01.01.001, 381.01.01.M001	Ground Station Monitor					
dcps	gsm	1	1	ea		12V/1.5A DC Power Supply	Sola	81-12-215-02	Newark		$65.02
cia1	gsm	1	1	ea	300.01.01.M003	Custom interface assembly					
ant	gsm	1	1	ea		Antenna	Larsen	EF900SNMO	Lindsey	EF900SNMO	$74.75
modem	gsm	1	1	ea		300/1200Baud Line Powered Modem	UDS	212ALP			
sbc	gsm	1	1	ea		PC-SBC, 1Meg RAM	Octagon	5025	Octagon	#3442	$536.00
sbc	gsm	2	1	ea		256K Flash EPROM DIP	Octagon		Octagon	#3162	$33.00
sbc	gsm	3	2	ea	381.01.01.M004	SBC Bracket					
dcdc	gsm	1	1	ea		12/5V dc-dc converter	Astec	MPS2100-8	Newark		$115.51
pwrassy	gsm	1	1	ea	381.01.01.M005	Power Interface Assembly					
box	gsm	1	1	ea		NEMA4 16"x12"x6" Box	Hoffman	A-16H1206ALLP			$259.58
box	gsm	2	1	ea	381.01.01.M002	Backplane	Hoffman	A-16P12AL			$16.90
box	gsm	3	2	ea	381.01.01.M001A	Pole-mount horizontal brackets					
box	gsm	4	2	ea	381.01.01.M001A	Pole-mount vertical brackets					
pcb	cia1	1	1	ea	C1	6.8uF Tantalum					
pcb	cia1	2	1	ea	C4	0.01uF Ceramic					
pcb	cia1	3	4	ea	C3,C4,C5,C7	4.7uF Tantalum					
pcb	cia1	4	2	ea	C51,C53	10uF Tantalum					
pcb	cia1	5	1	ea	C52	150 uF 16V Tantalum	Panasonic	ECS-F1CE157	Digikey		$9.91
pcb	cia1	6	1	ea	C54	10uF Electrolytic					
pcb	cia1	7	1	ea	C55	0.1uF Tantalum					
pcb	cia1	8	1	ea	C56	0.1uF Ceramic					
pcb	cia1	9	2	ea	J1, J2	Header 5x2, 90deg					
pcb	cia1	10	1	ea	J3	Header 8x2, 90deg					
pcb	cia1	11	1	ea	J4	Header 10x2, 90deg					

Component	Part of	Item	Qty	Unit	Reference	Description	Mfr	Mfr Model	Vendor	Vendor Model	(Price)
pcb	cia1	12	1	ea	J5	Header 7x2, straight					
pcb	cia1	13	1	ea	Q1	PNP 60V 0.6A BJT			Digikey	2N2907A-NDK	
pcb	cia1	14	7	ea	R1,R2,R3,R4,R5, R6,R7	200ohm 5% 1/8W					
pcb	cia1	15	1	ea	R8	2.5M 5% 1/8W					
pcb	cia1	16	1	ea	U1	74LS247 7SEG LED Driver	TI	SN74LS274			
pcb	cia1	17	1	ea	U2	CMOS 555 Timer	Harris	IPA7555			
pcb	cia1	18	1	ea	U3	MAX232 5V RS232 Driver/Rcvr	Maxim	MAX232CPE			
pcb	cia1	19	1	ea	U4	7475 Quad Flip-Flop	TI	SN7475N			
pcb	cia1	20	1	ea	U50	7400 Quad NAND Gate	TI	SN7400N			
pcb	cia1	21	1	ea	381.01.01.002, 381.01.01.M003A	Custom Printed Circuit Board					
radio	cia1	1	1	ea		900MHz Radio	Proxim	RXA-300			
commbrktA	cia1	1	1	ea	381.01.01.003B	Comm PCB bracket					
commbrktB	cia1	1	1	ea	381.01.01.003C	Radio bracket					
pwrassyparts	pwrassy	1	1	ea		3-point screw terminal block					
pwrassyparts	pwrassy	2	1	ea		SPST toggle switch					
pwrassyparts	pwrassy	3	1	ea		120V 0.5A fuse holder					
pwrassyparts	pwrassy	4	1	ea		120V 0.5A slow-blow fuse					
pwrassyparts	pwrassy	5	1	ea		5V panel-mount LED					
pwrassyparts	pwrassy	6	1	ea	381.01.01.M005A	Main bracket					
pwrassyparts	pwrassy	7	1	ea	381.01.01.M005B	Long minor bracket					
pwrassyparts	pwrassy	8	1	ea	381.01.01.M005B	Small minor bracket					

Appendix B. Source Contact Information

Advantech Embedded Computing Group
800-866-6008 http://www.advantech.com
15375 Barranca Parkway
Suite A-106
Irvine, CA 92618

ARC Electronics
800-926-0226 http://www.arcelect.com
814 Wild Horse Vly. Rd. Suite H
Katy, TX 77450

ASTEC AMERICA, INC.
(760) 930-4600 http://www.astec.com
5810 Van Allen Way
Carlsbad, CA 92008

Digi-Key Corporation
800-344-4539 http://www.digikey.com
701 Brooks Avenue South
Thief River Falls, MN 56701

Ewing-Foley Inc.
408-342-1200 http://www.EwingFoley.com
10495 Bandley Avenue
Cupertino, CA 95014-1972, USA

Hoffman Enclosures
http://www.hoffmanonline.com
See Local Representative such as Ewing-Foley, Inc.

Radiall/Larsen Antenna Technologies
800-ANTENNA http://larsenantennas.com
3611 NE 112th Avenue
Vancouver, WA 98682
Distributed by, among others, Lindsey Engineering

Lindsey Engineering
217 621-3094 http://www.shout.net/~rlindsey/LindseyEng.html
1908 Kenny Avenue
Champaign, IL 61822

Motorola Transmission Products Company
http://www.motorola.com

Newark Electronics
1-800-4-NEWARK   http://www.digikey.com

Octagon Systems Corporation
303–430–1500   http://www.octagonsystems.com
6510 W. 91st Ave
Westminster, CO 80031 USA

Xetron
(513) 881-3500   http://www.xetron.com/commain.html
460 West Crescentville Road
Cincinnati, Ohio 45246

Universal Data Systems
See Motorola Transmission Products Company

Appendix C. Drawings

The drawing list below identifies the drawings generated for the GSM, including sketches of the mechanical packaging components and digital images of the prototype. The GSM Wiring Diagram and the Communications Interface Adapter schematic were produced using Orcad Capture 7.0a. The CD-R provided with this report contains electronic versions of these drawings along with additional photographs and product descriptions

Table 2 List of Drawings

Drawing Number	Description	Format
381.01.01.001	GSM Wiring Diagram	Orcad
381.01.01.002	Communications Interface Adapter	Orcad
381.01.01.002A	Comm Interface PCB Photo	JPG
381.01.01.M001	GSM Box Photo	JPG
381.01.01.M001A	Pole Mount Supports	AutoCAD
381.01.01.M002	Backplane Mechanical	AutoCAD
381.01.01.M002A	Backplane Assembly	JPG
381.01.01.M003	Comm Interface Assembly Photo	JPG
381.01.01.M003A	Comm Interface PCB Layout	AutoCAD
381.01.01.M003B	Comm Bracket A	AutoCAD
381.01.01.M003C	Comm Bracket B	AutoCAD
381.01.01.M004	SBC Bracket	AutoCAD
381.01.01.M005	Power Interface Photo	JPG
381.01.01.M005A	Power Interface Main Bracket	AutoCAD
381.01.01.M005B	Power Interface Minor Brackets	AutoCAD

Drawing 381.01.01.001 shows the wiring connections needed to connect the components together. Connections are generally made with single-conductor 18 AWG wire, except for ribbon cables connecting the SBC, communications interface board, and digital radio, and coaxial connections for the antenna.

Drawing 381.01.01.002 shows the schematic representation of the communications interface board. Photocopied pages from the SBC manual and digital radio describing the pinouts for the mating connectors has been included in this documentation package to support interpretation of this schematic. Drawing 381.01.01.002A is a photograph of the circuit side of the prototype communications interface board, showing the extensive engineering changes. This photograph serves as layout documentation in lieu of an actual final circuit layout, omitted due to a probable need for future design changes. The 7-segment LED display was connected using a ribbon cable soldered on one end to a 14-pin DIP socket and on the other end to individual solder pads on the circuit board (noted as J5 through J12 on Drawing 381.01.01.M003A). The schematic

381.01.01.002 shows this simply as a dual-row header connector with pins numbered as on the DIP socket.

Drawing 381.01.01.M001 is a photograph of the overall GSM package. Note the single visible pole-mount cross-support bolted through the box mounting tabs to the two pole-mount vertical supports, The vertical supports provide contact edges for the pole, while the cross-supports include a hole through which a lag screw may be screwed to the pole.

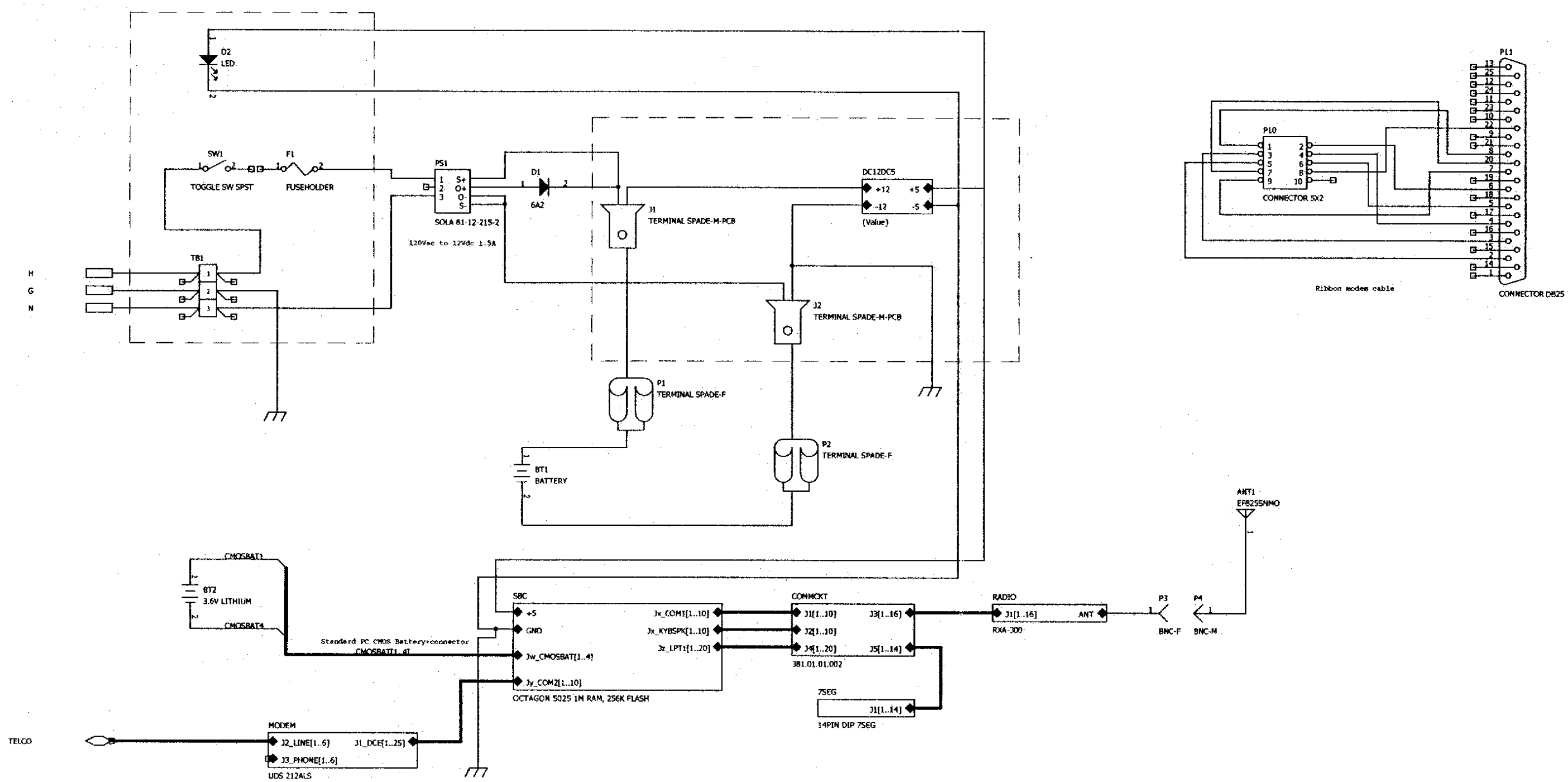
Drawing 381.01.01.M002 shows the placement of the holes drilled in the backplane for mounting the power interface assembly, modem, SBC mounting brackets, communications interface assembly, and power supply.

Drawing 381.01.01.M003 is a photograph showing the assembly of the communication interface, viewed from above. Drawings 381.01.01.M003A shows the part placement on the communications interface circuit board (see 381.01.01.002A). Drawings 381.01.01.M003B and C are mechanical drawings of the communication interface mounting brackets.

Drawing 381.01.01.M004 shows the mechanical dimensions of the SBC mounting brackets. A piece of perforated fiberglass prototyping board mounted to the lower side of the SBC brackets was used to mount the dc-dc converter and spade terminals for connecting the battery.

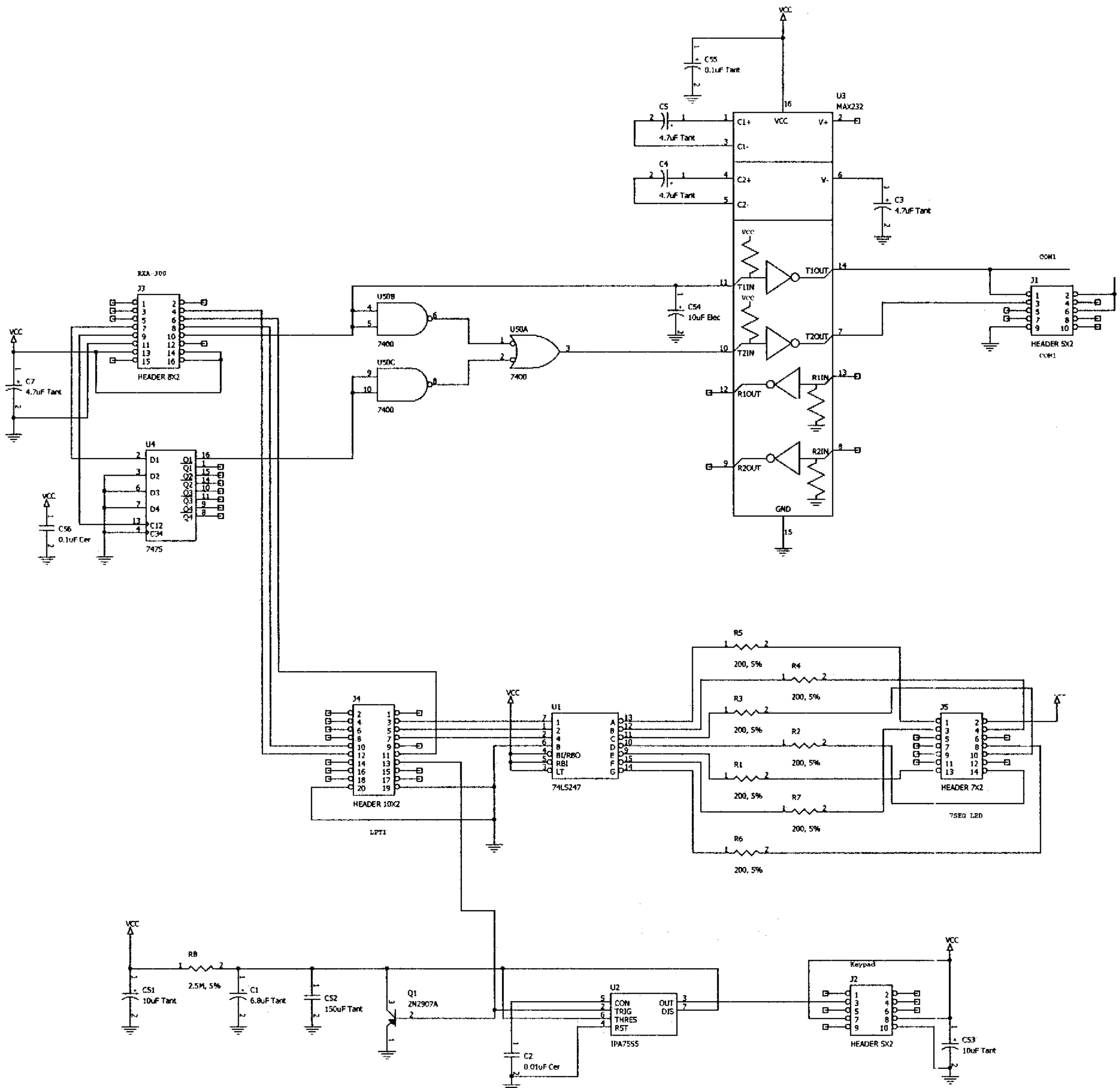
Drawing 381.01.01.M005 is a photograph of the power interface assembly exposed to show the bracket assembly. Drawings 381.01.01.M005A and B show the mechanical dimensions of the three power interface brackets.

Additional digital photographs of the GSM are included in the electronic documentation package.



Endecon Engineering
2500 Old Crow Canyon Road, Suite 220
San Ramon, Ca 94583

Title		
GSM Wiring Connection Diagram		
Size: C	Document Number: 381.01.01.001	Rev: 0
Date: Tuesday, May 02, 2000	Sheet 1 of 1	

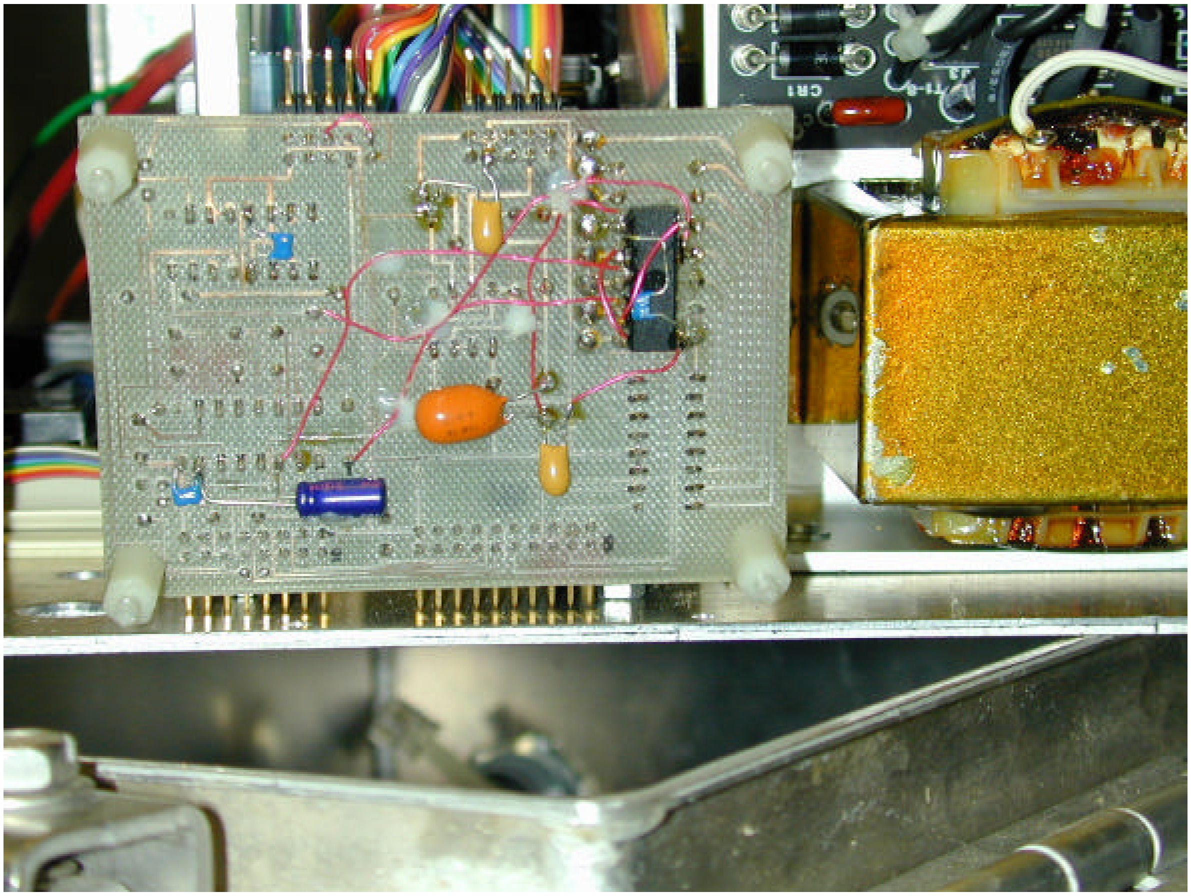


Notes:

1) Q1 appears to be non-functional, a design error. Internal MOSFET in 7555 between pins 7 and 1 controlled by 6 implements reset function.

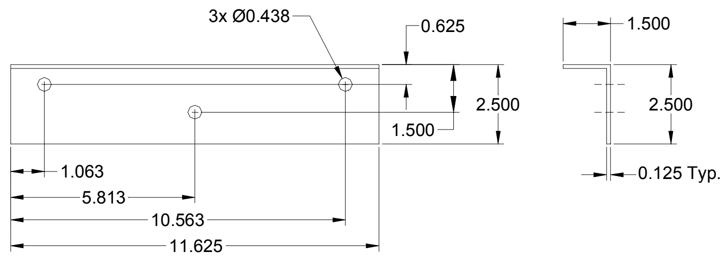
Endecon Engineering
San Ramon, Ca 94583
2500 Old Crow Canyon Road, Suite 220

Title	GSM PCB	
Size: C	Document Number: 381.01.01.002	Rev: D
Date: Tuesday, May 02, 2000	Sheet 1 of 1	

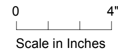


Communications Interface PCB, 381.01.01.002A

GSM Enclosure, 381.01.01.M001

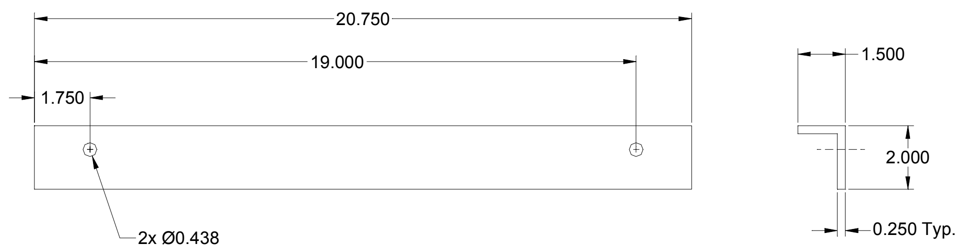


1. Material: Angle aluminum 2-1/2 x 1-1/2 x 1/8
2. Quarter scale: All dimensions in inches



CROSS SUPPORT

1. Material: Angle aluminum 2 x 1-1/2 x 1/4
2. All dimensions in inches

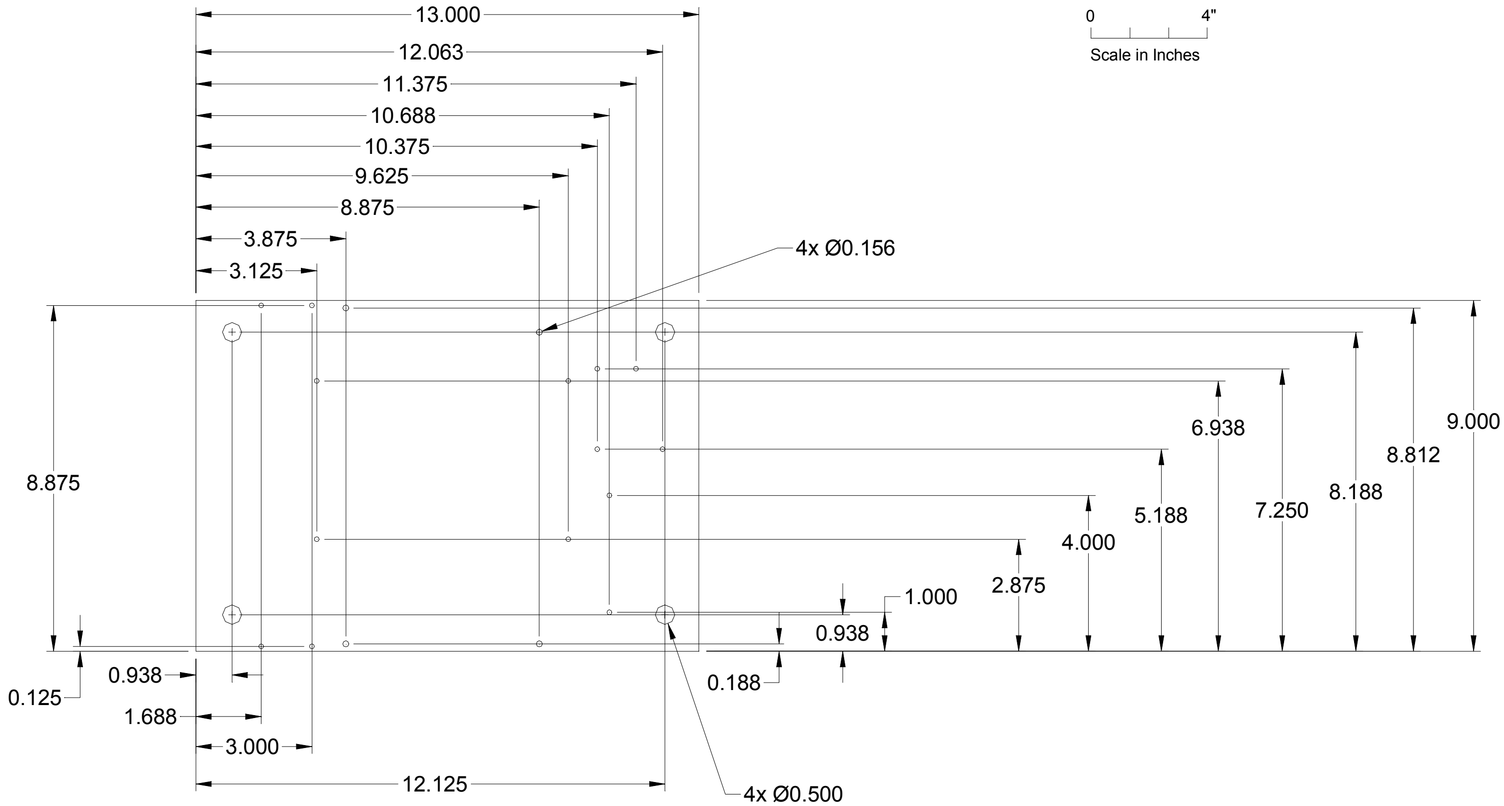


VERTICAL SUPPORT

Pole Mount Supports
Dwg 381.01.01.M001A

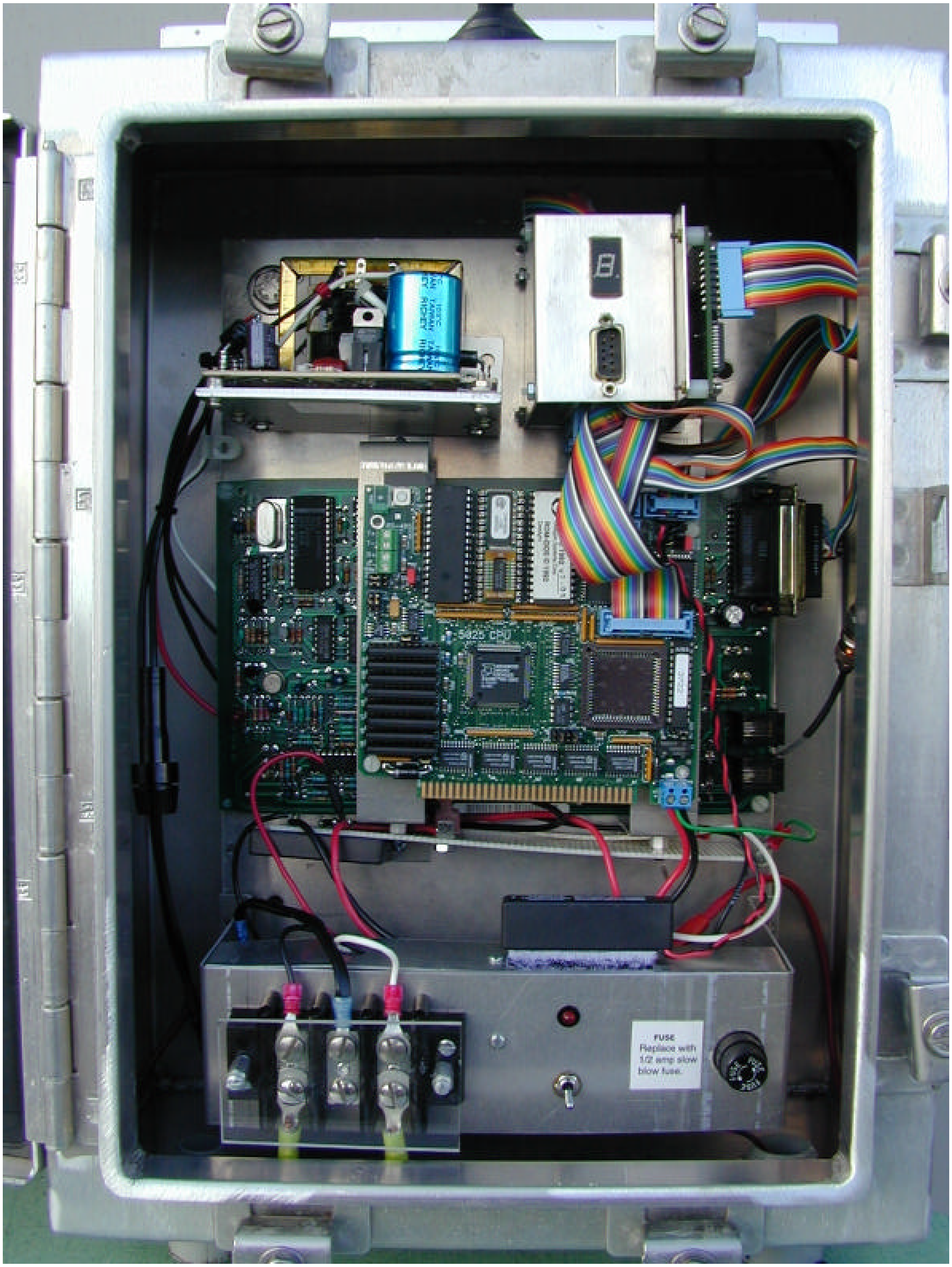
000634/381.01.01.M001A

NOTES
1. Material: 0.100 aluminum
2. Quarter scale: All dimensions in inches
3. 0.125 dia. holes unless otherwise noted

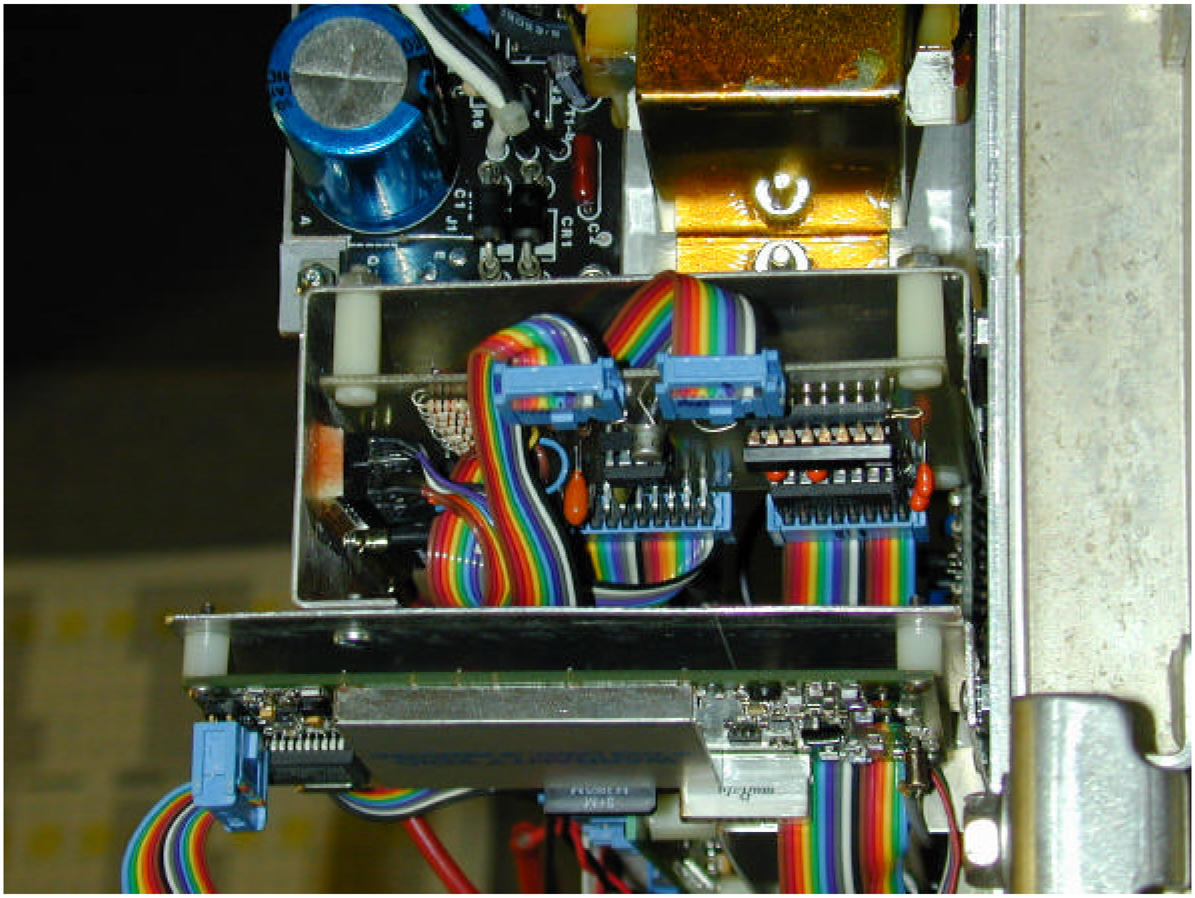


Backplane Mechancial
Dwg 381.01.01.M002

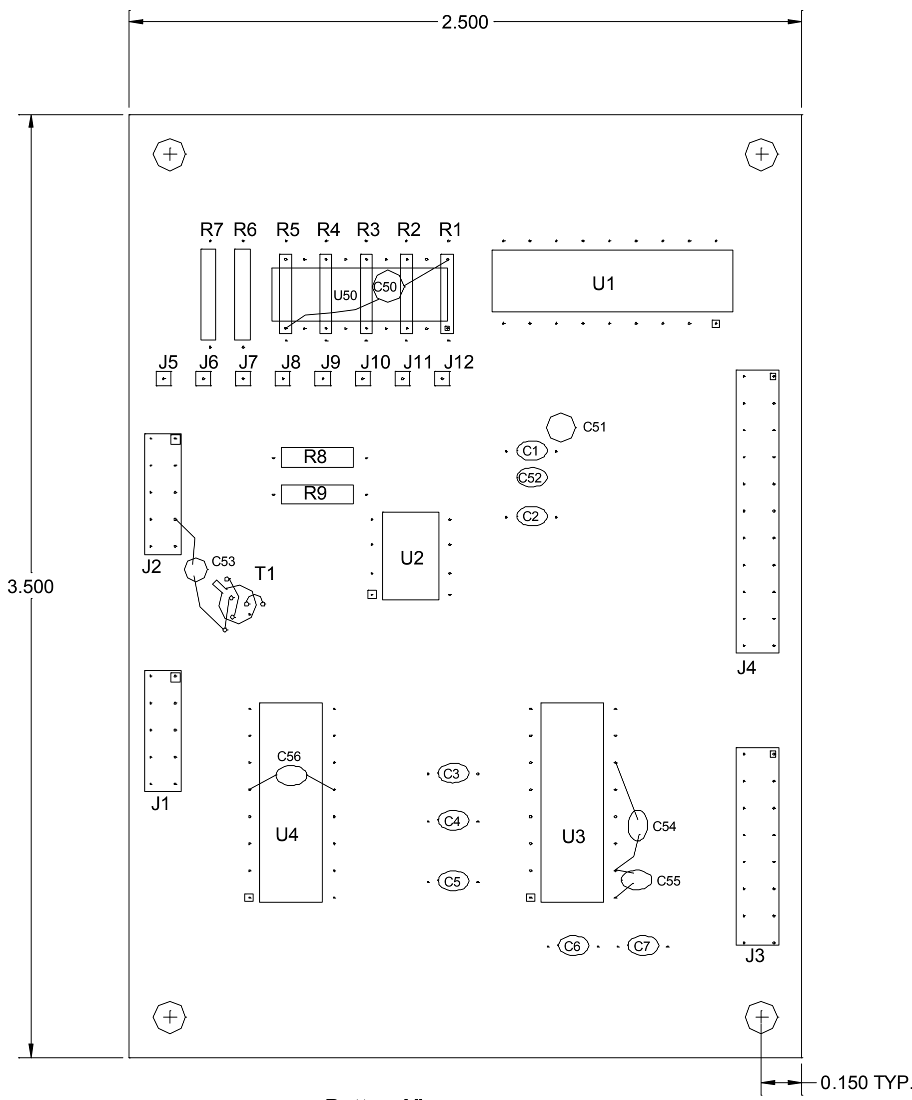
000633/381.01.01.M002



Backplane Assembly, 381.01.01.M002A



Communications Interface Assembly, 381.01.01.M003



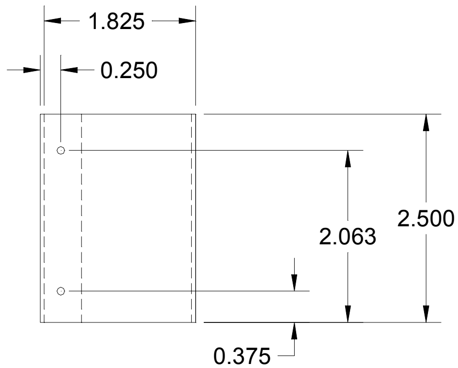
Bottom View

NOTES
1. Leads of Q1 swap thru holes 1 and 2.
Detailed layout not documented due
toextensive modifications.

NOT TO SCALE

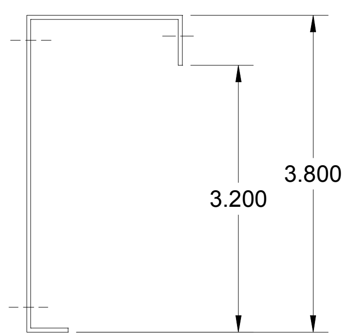
Communication Interface PCB Layout
Dwg 381.01.01.M003A

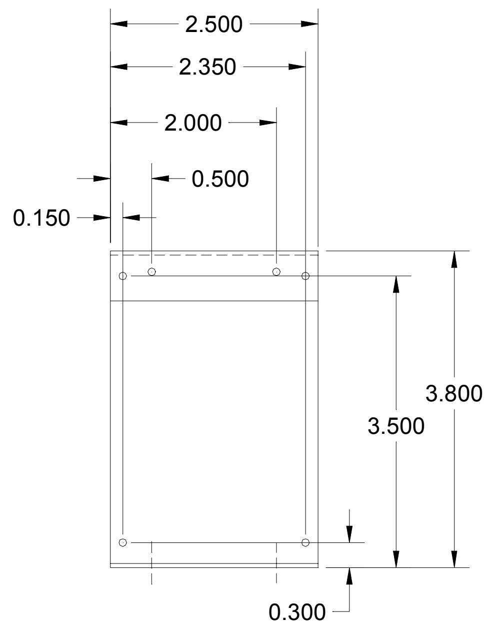
000633/381.01.01.M003A



NOTES
1. Material: 0.050 aluminum
2. Half scale: All dimensions in inches
3. Holes clear for #6 screw unless otherwise noted

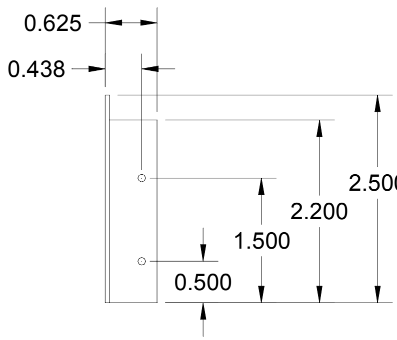
0 2"





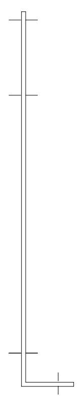
Communications Bracket A
Dwg 381.01.01.M003B

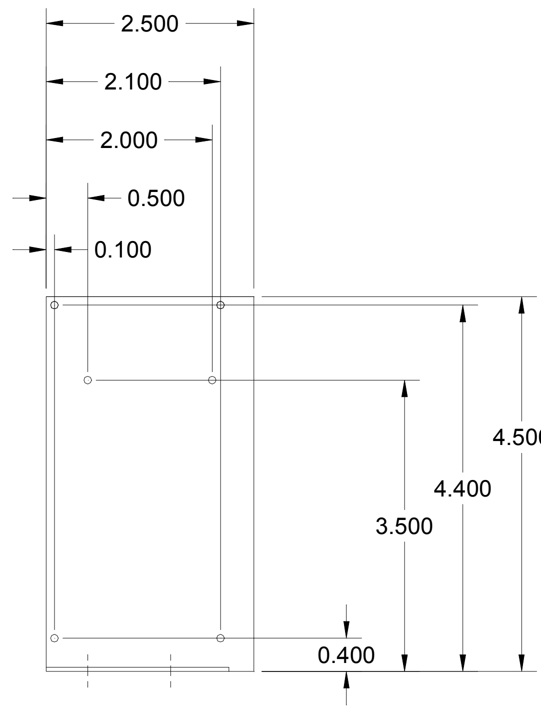
000633/381.01.01.M003B



NOTES
1. Material: 0.050 aluminum
2. Half scale: All dimensions in inches
3. Holes clear for #6 screw unless otherwise noted

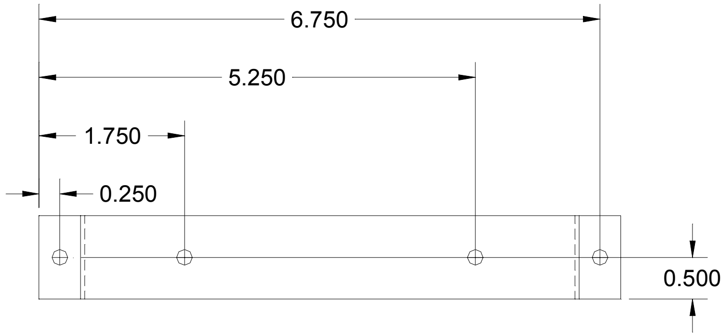
0 2"



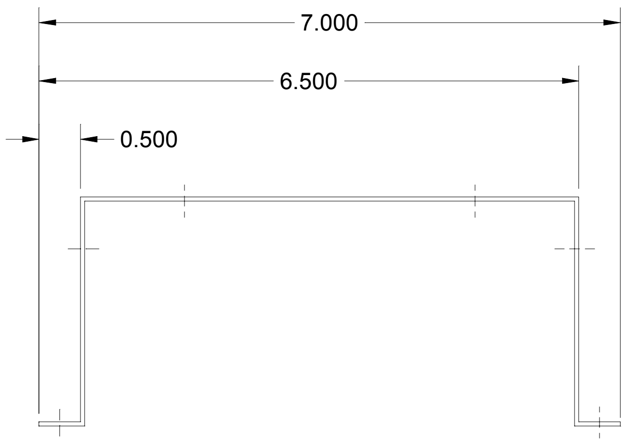


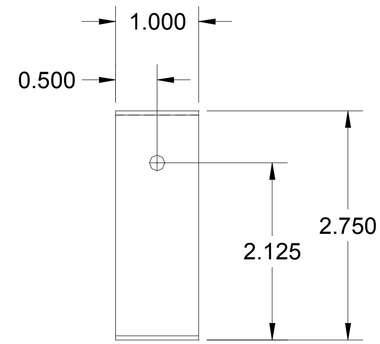
Communications Bracket B
Dwg 381.01.01.M003C

000633/381.01.01.M003C

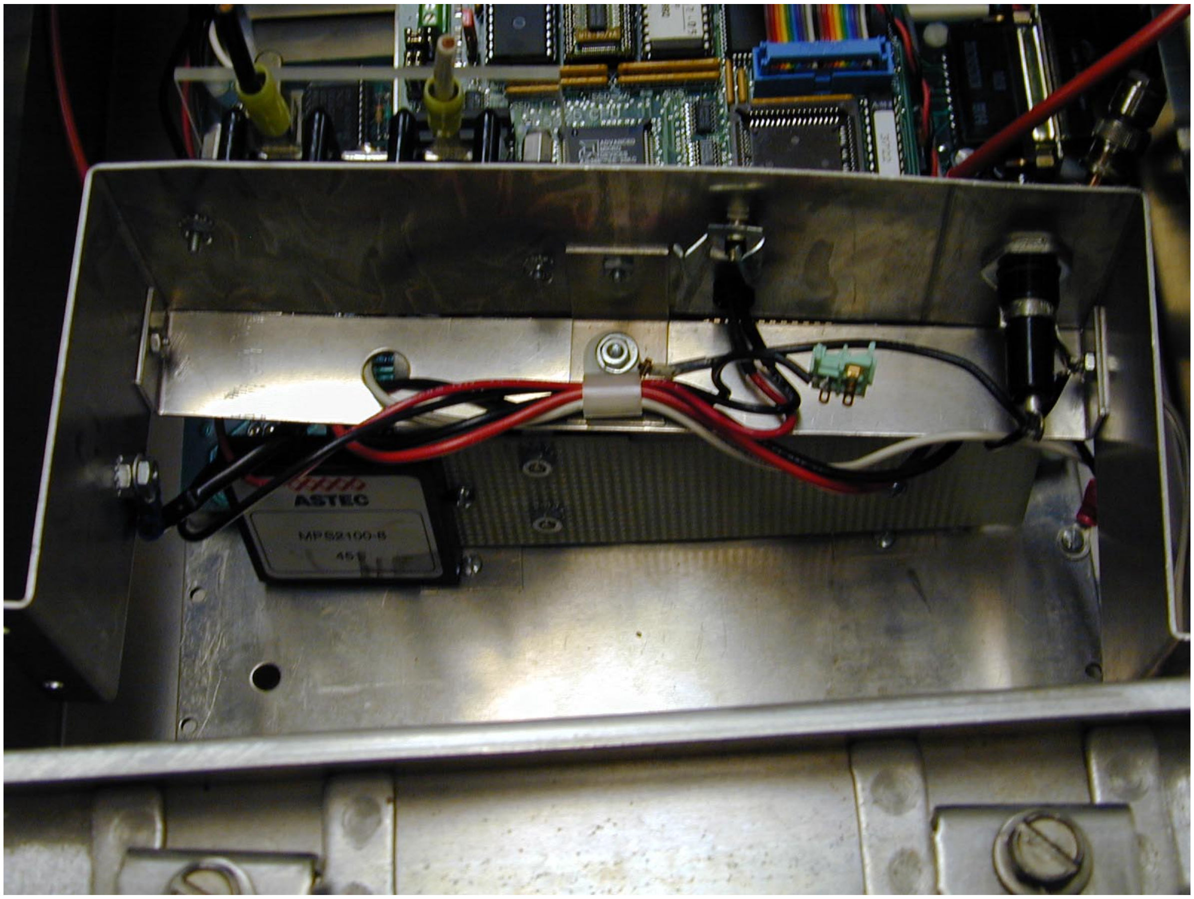


NOTES
1. Material: 0.050 aluminum
2. Half scale: All dimensions in inches
3. 0.188 dia. holes unless otherwise noted



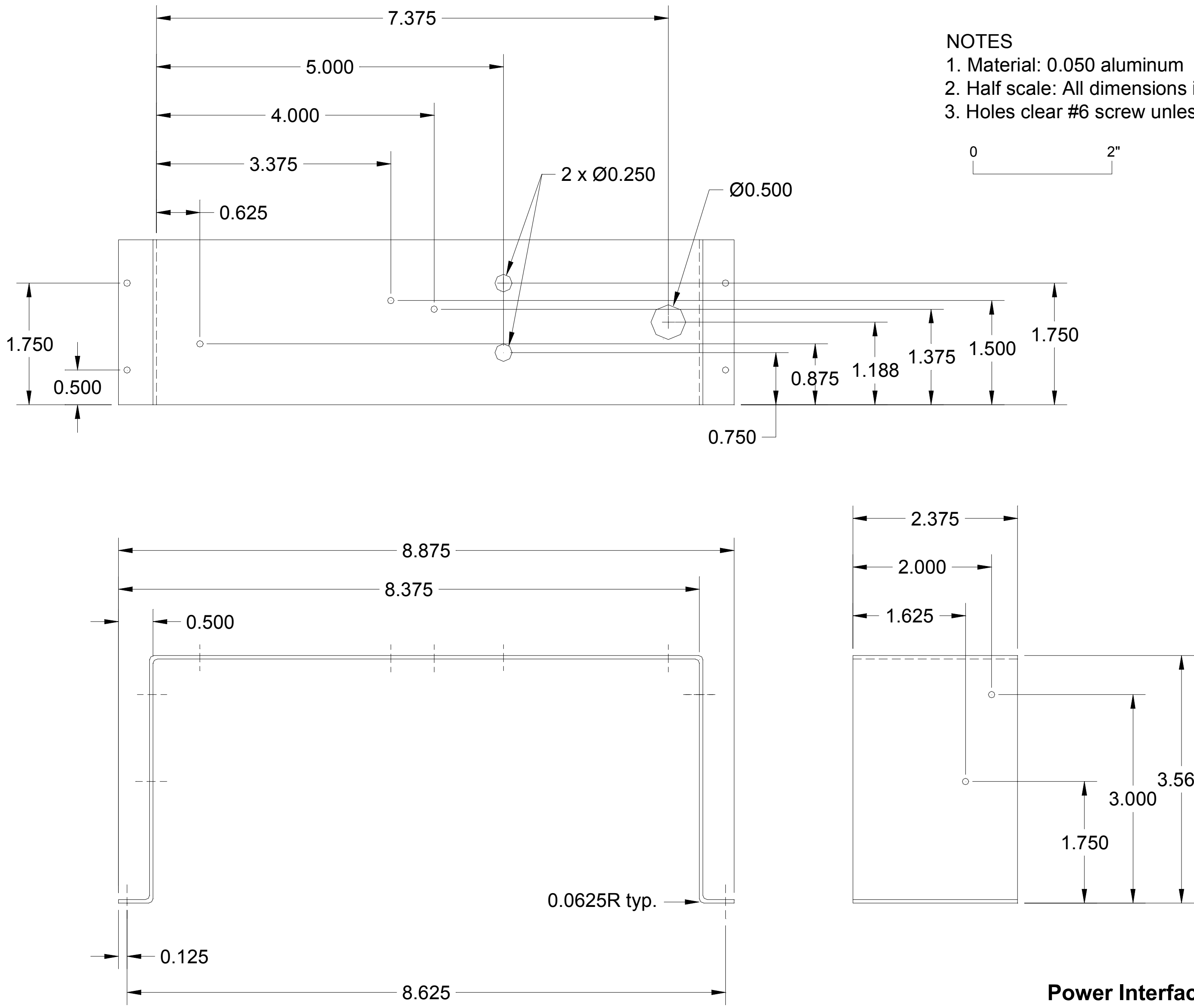


SBC Bracket
Dwg 381.01.01.M004

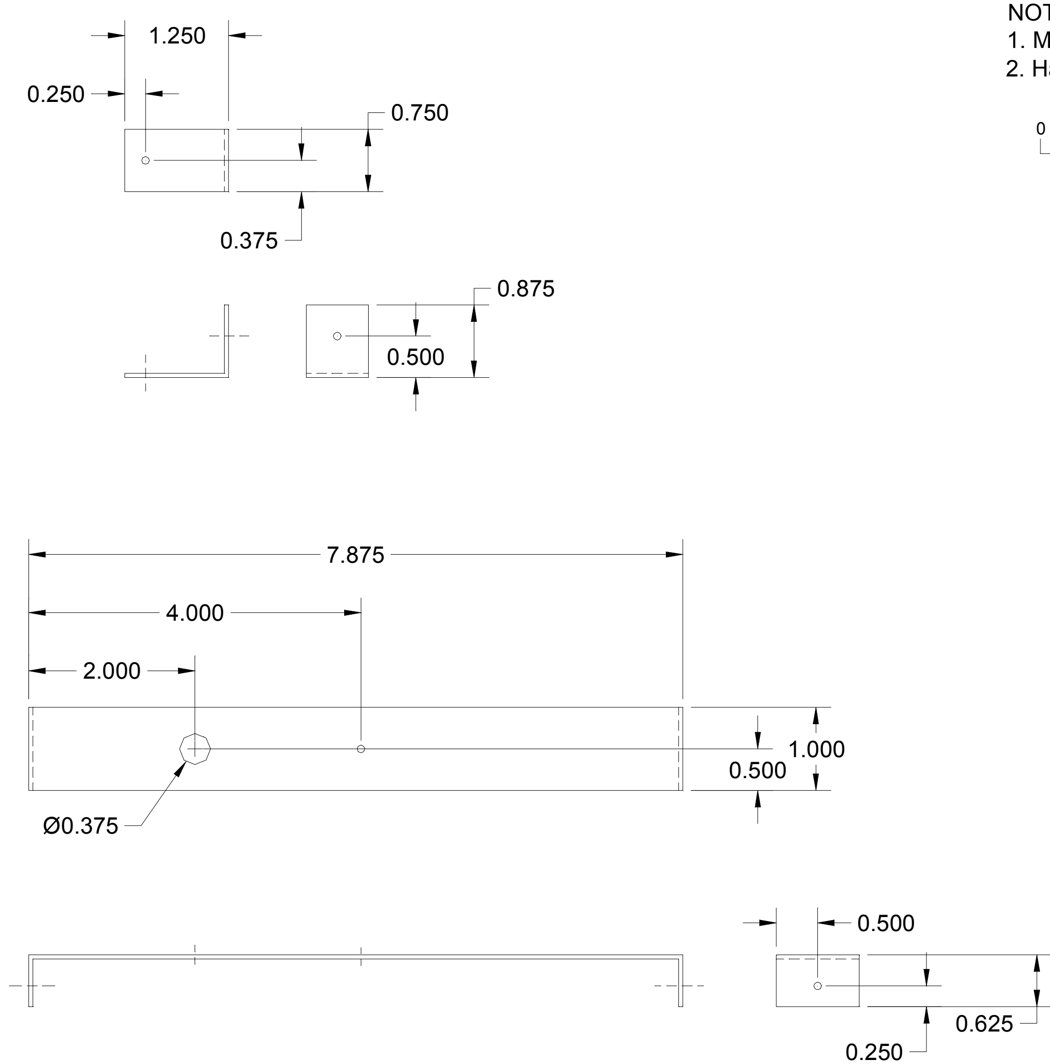


Power Interface, 381.01.01.M005

NOTES
1. Material: 0.050 aluminum
2. Half scale: All dimensions in inches
3. Holes clear #6 screw unless otherwise noted



Power Interface Main Bracket
Dwg 381.01.01.M005A



NOTES
1. Material: 0.050 aluminum
2. Half scale: All dimensions in inches

Power Interface Minor Brackets
Dwg 381.01.01.M005B

Appendix IV

Ground Station Software Documentation

PG&E Research and Development

Birdstrike Monitor Ground Station

Documentation

Version 1.0 - 9/95

Printed 09/30/95

Prepared by:

Greg Herlein, Technologist
Research and Development Lab

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OVERVIEW OF PROGRAM

Purpose

The Birdstrike Monitor Ground Station acts as an interface between the sensors and the user of the data. The sensors are line mounted and detect bird hits on the line by an accelerometer. The sensors use a spread-spectrum radio to transmit the collected data. The ground station uses a matching radio to receive the data. Data packets are written to a static-ram disk on the ground station. Users may call the Ground Station via a modem and download the data files. The modem used by the Ground Station is 1200 baud.

Operating System

The Ground Station uses ROM-DOS 6.20 as its base operating system. A program entitled BIRDOS.EXE runs automatically when the Ground Station reboots. This is the "operating system" level of the Ground Station.

Executable Code

The program BIRDOS.EXE will refer to the file D:\BIRDINI (on static ram) to determine if it ought to run the executable program BIRD.EXE, which also resides on D:\ (in static ram). This scheme allows changes to the executable code to be uploaded from remote. BIRDOS.EXE is a fully working version of BIRD.EXE that is "burned" into the flash ram disk on the embedded computer. BIRD.EXE may be several revision levels newer than BIRDOS.EXE, and should be used unless a new version is being uploaded.

Commercial Libraries

The Ground Station uses the Greenleaf CommLib communications library.

Disk Drives

The Ground Station uses flash ram and static ram as disk drives. Drive A: is a 256k flask ram disk. Drive D: is a 1.5M static ram disk. The clock and the static ram are battery backed (separately even from the battery backup for the Ground Station itself), protecting the data files on the Ground Station. Flash ram is non-volatile (loss of power will not affect it).

OPERATION

Basic Commands

The system will automatically answer the phone and display a message similar to the following:

BIRDSTRIKE MONITOR GROUND STATION
Version 1.0.6b EXE WDT Copyright 1995 PG&E
>

The > symbol is the prompt. You may enter commands anytime you see the prompt. NOTE: if you make a mistake, you cannot backspace! Just hit enter and then retype the line. Backspace and command line history are features that might someday be added (probably not though). All commands begin with the * character. Commands may be upper or lower case (the system converts them all to upper case anyway).

***DIR**

This gives a list of the files on the directory (and the file sizes). You can specify command line parameters (like *.*). A useful command is *DIR *.0?? which will list only data files.

***DEL**

This command deletes files. It also takes wildcards, or specific filenames. You may not use *DEL *.* (since that would kill the program file too!).

***STATUS**

This command will list the sensors by number, with a date-time code of the last heartbeat packet and the battery voltage reported in that packet. All heartbeat packets are logged to HARTBEAT.CSV, each new one appending to the end of the file. Only the most recent heartbeat will be reported by *STATUS.

***SYSTEM**

This command gives some basic information about the system. It is mostly useful for diagnostic purposes.

***DOWNLOAD**

This is used to download files. You may specify a file by name, or use wildcards. The Ground Station uses the ZMODEM protocol.

***UPLOAD**

This is used to upload files You may specify a file by name, or use wildcards. The Ground Station uses the ZMODEM protocol.

***DONE**

This is how you tell the Ground Station that you are all done. It will say good-bye and hang up.

***VER**

This is a diagnostic command that causes the Ground Station to tell you what version of the program it is running.

***TIME [NOW] [HH:MM:SS]**

This command has two forms. The first uses the word "NOW" after the *TIME command, causing the system to print what time it thinks it is. The second allows you to set the time by specifying HH:MM:SS.

***DATE [MM/DD/YY]**

This command allows you to specify a new system date.

***OS**

If the Ground Station is running the executable program BIRD.EXE, this command is available. It causes the executable program to exit. This also hangs up the phone. The Ground Station is left running BIRDOS.EXE.

***BIRD**

This is the opposite of *OS. It is only available if BIRDOS.EXE is running, and it causes BIRD.EXE to load and run. This also hangs up the phone.

***REBOOT**

This command causes the Ground Station to reboot.

GROUND STATION NUMERIC DISPLAY

The Ground Station has a numeric display internal to the enclosure. This display indicates a number that reflects what the Ground Station is doing. These numbers are:

c	Idle - no program running (looks like a small letter c)
0	Waiting
1	Initializing system
2	Initializing the modem
3	Initializing the radio
5	On-line with modem (someone has called in)
6	Getting data from radio
7	Writing a data file
8	Transferring a file via the modem
9	Error condition detected

On booting, the system will cycle between c,0,2,3,0,2,3, and back to 0. This reflects its initial idle state, followed by the loading of BIRDOS, initializing the modem and the radio (numeral 1 actually flashed by too fast to read), then it loads BIRD, and the radio and the modem are initialized again. The Ground Station ought to be in 0 most of the time.

INITIALIZATION FILE

The Ground Station uses D:\BIRDINI as the initialization file. If it cannot be found, then it tries to use D:\BIRDINI (on the flash ram disk). The INI file has several parameters, detailed below:

BIRD-D:\BIRD.EXE

This is the default setting for BIRD. Do not change this.

RunBIRD=Y

This is the default setting for RunBIRD. If Y (yes) then the BIRD executable program will run. If N (or any non-Y value) then it will not be loaded by BIRDOS.

SysPath=D:

This is the default path for the system. Do not change this.

LogFile=BIRD.LOG

This is the default filename for all system logs. If you desire to have the logs be written to a file of a different name, you could change this value to accomplish that.

FILE FORMATS

The Ground Station collects two kinds of data packets: heartbeats and data. The Ground Station prepends a few bytes to what is received from the sensor. File formats that the Ground Station writes to disk are shown below:

Heartbeat

00 01	COUNT	Integer. Number of bytes detected in the packet from the radio.
02	OK	Byte. If 0x00 the packet was detected as having flaws when it arrived from the radio. If 0x01 it was OK.
03	AA	first two bytes are AA AA (a start frame delimiter).
04	AA	
05	TYP	Type Code. 0x02 is a heartbeat packet.
06	ID	A single byte ID number to identify the originating sensor.
07 08	BATT	Low-byte Hi-byte of a 12 bit value. The decimal value of the resulting (16 bit) int is the number of millivolts detected from the battery. Multiply this by 4.32 to get true battery voltage.
09	CR	End delimiter (0x0D).

Data

00 01	COUNT	Integer. Number of bytes detected in the packet from the radio.
02	OK	Byte. If 0x00 the packet was detected as having flaws when it arrived from the radio. If 0x01 it was OK.
03	AA	first two bytes are AA AA (a start frame delimiter).
04	AA	
05	TYP	Type Code. 0x04 is a data packet.
06	ID	A single byte ID number to identify the originating sensor.
07	CR	End of header delimiter (0x0D).
08 - 8232	DATA	Low-byte Hi-byte of a 12 bit value. The decimal value of the resulting (16 bit) int is the number of millivolts detected by the sensor. To arrive at the number of g's detected, convert by: $g=(2048 - n)*0.1$ There are 16 blocks of 512 bytes of data. Each block is followed by two bytes 0xFF 0xFF as block delimiters.
8233 8234	TEMP	Low-byte Hi-byte of a 12 bit value. The decimal value of the resulting (16 bit) int is the number of millivolts detected from the temperature sensor. Multiply this by 0.1 to get true temperature in degrees Celsius.
8235	CR	End delimiter (0x0D).